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**DOD SPACE TRANSPORTATION SYSTEM (STS) COMMAND AND CONTROL
DATA SYSTEM STUDY. VOLUME IV. AFSCF/SHUTTLE MISSION
CONTROL CENTER REQUIREMENTS ANALYSIS**

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Philco-Ford Corporation

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)		
<p>This six volume report presents a Command and Control Data System (CCDS) concept for support of DOD Space Transportation System (STS) missions launched from VAFB or KSC. It describes the CCDS concept in terms of its functional control elements (e.g., Mission Control, Launch Control, etc.), their interfaces, and functional requirements for personnel, data processing, display, command/control, and communications. Candidate operating positions required in the Shuttle Mission Control Center to support STS missions are described and a sample annex to an Orbital Requirements Document (ORD) for the interim upper stage is</p>		

presented. The joint use of the JSC Shuttle Mission Simulator (SMS) was investigated and the DOD SMS capability requirement determined. Budgetary cost and schedule estimates for a DOD SMS were provided based on NASA budgetary figures.

The complete set of volumes comprising this report includes: Volume I - Study Summary; Volume II - System Requirements Analysis Definition; Volume III - Command and Control Data System Concept Development; Volume IV-AFSCF/Shuttle Mission Control Center Requirements Analysis; Volume V - DOD Shuttle Mission Simulator Requirements Analysis and Resource Acquisition Schedules; Volumes VI - Secure Data and Equipment Handling.

FOREWORD

This study was performed for the United States Air Force Space and Missile Systems Organization (SAMSO) in accordance with the statement of work for the DOD Space Transportation System CCDS Study. It was performed during the period of 1 February to 30 October 1974 under contract F04701-74-C-0260.

The complete set of volumes comprising this report includes:

- Volume I - Study Summary
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- Volume VI - Secure Data and Equipment Handling

This study was performed under the direction of DOD/SAMSO. Aerospace Corporation provided assistance to SAMSO. This study was performed by Philco-Ford's Western Development Laboratories Division, Philco Houston Operation with key participation of personnel from Philco-Ford's Satellite Control Facility Operation at Palo Alto.

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This final report has been reviewed and is approved. Readers are cautioned that the material presented herein represents the findings and conclusions of the Philco-Ford Study Group and does not necessarily define a DOD/SAMSO position, policy, or decision.

Robert W. Lindemuth

Maj. R. Lindemuth, USAF Study Monitor

PREFACE

BACKGROUND

The Command and Control Data System (CCDS) Study, in previous tasks, analyzed the Space Transportation System (STS) operations in order to develop a Department of Defense (DOD) CCDS concept to support all STS operations phases. CCDS is a collective term since it comprises the ground-based data systems and their inter- and intra-system communications required for support of the DOD STS. The CCDS concept developed comprised seven functional control elements: six primarily to support turnaround and launch operations and one to exercise overall mission control and to support operations from liftoff through rollout. These are the Turnaround Control, Launch Control, Range, Payload Checkout Control, Operations Management Control, and Central Data Elements for support of turnaround and launch, and for the flight operations and mission management, a Mission Control Element.

The CCDS concept developed is neither a single nor a totally new system. Much of the CCDS currently exists in the USAF Satellite Control Facility (SCF) and the Vandenberg Air Force Base (VAFB) data and communications systems. NASA-operated systems and facilities are to be utilized where possible to avoid expensive duplications, e.g., mission planning systems or optional use of the Tracking and Data Relay Satellite (TDRS) for contingency reaction. NASA systems for this study were considered external to the DOD CCDS. In applications requiring new equipment, it is expected that NASA-developed systems will be installed in DOD facilities to the maximum extent possible (e.g., Launch Processing System).

The DOD CCDS was considered a functional entity for purposes of this study to ensure the compatibility of its several elements by developing its functional requirements as an integrated system. This will permit subsequent integration of its elements to be accomplished efficiently and effectively, and will ensure completeness of the total STS Ground Support System concept.

Subsequent to the start of this study, a change in the work to be done was directed by the Air Force which modified Tasks IV and V. Task IV was modified to delete the subtask to define a Shuttle Mission Control Center (SMCC), which is part of the Mission Control Element (MCE). It was replaced with a subtask to define the Air Force Satellite Control Facility (AFSCF) and SMCC requirements

and a subtask to conduct the necessary analysis to define the DOD Shuttle Mission Simulator (SMS) capabilities required. Documentation resulting from this task is the Orbital Requirements Document (ORD) which defines the AFSCF/SMCC requirements to support the STS operation and volumes IV and V of this report. The ORD is published separately and comprises the ORD for support of the Orbiter, external tank (ET), and solid rocket boosters (SRB's). A sample annex for the ORD defining the requirements levied on the AFSCF by the interim upper stage (IUS) is contained in Part 2 of this volume. Because of the lack of detail available on the IUS, this sample annex is a guide only. It is not a vehicle levying requirements on the SCF. Figure 1 illustrates the relationship of this task to the other tasks of the DOD STS CCDS Study.

This volume, in addition to the IUS sample annex to the ORD, provides backup information, rationale, and/or qualification to material contained in the ORD.

TASK OBJECTIVES

The task objectives defined in this volume are:

- A. Make a preliminary determination of the operating positions required within the SMCC.
- B. Determine the functions to be performed at, and the information, control, and communication requirements of, each operating position.
- C. Develop a sample annex to the ORD detailing, to the extent possible with current IUS program definition, the support requirements levied on the USAF SCF by the IUS.

ORGANIZATION

This volume is presented in two parts. Part 1 presents the SMCC/AFSCF requirements analysis results that are not items for the ORD. Section 2 includes an estimate of the operating positions required within the SMCC to conduct STS operations together with their information, control, and communication requirements. Section 3 discusses

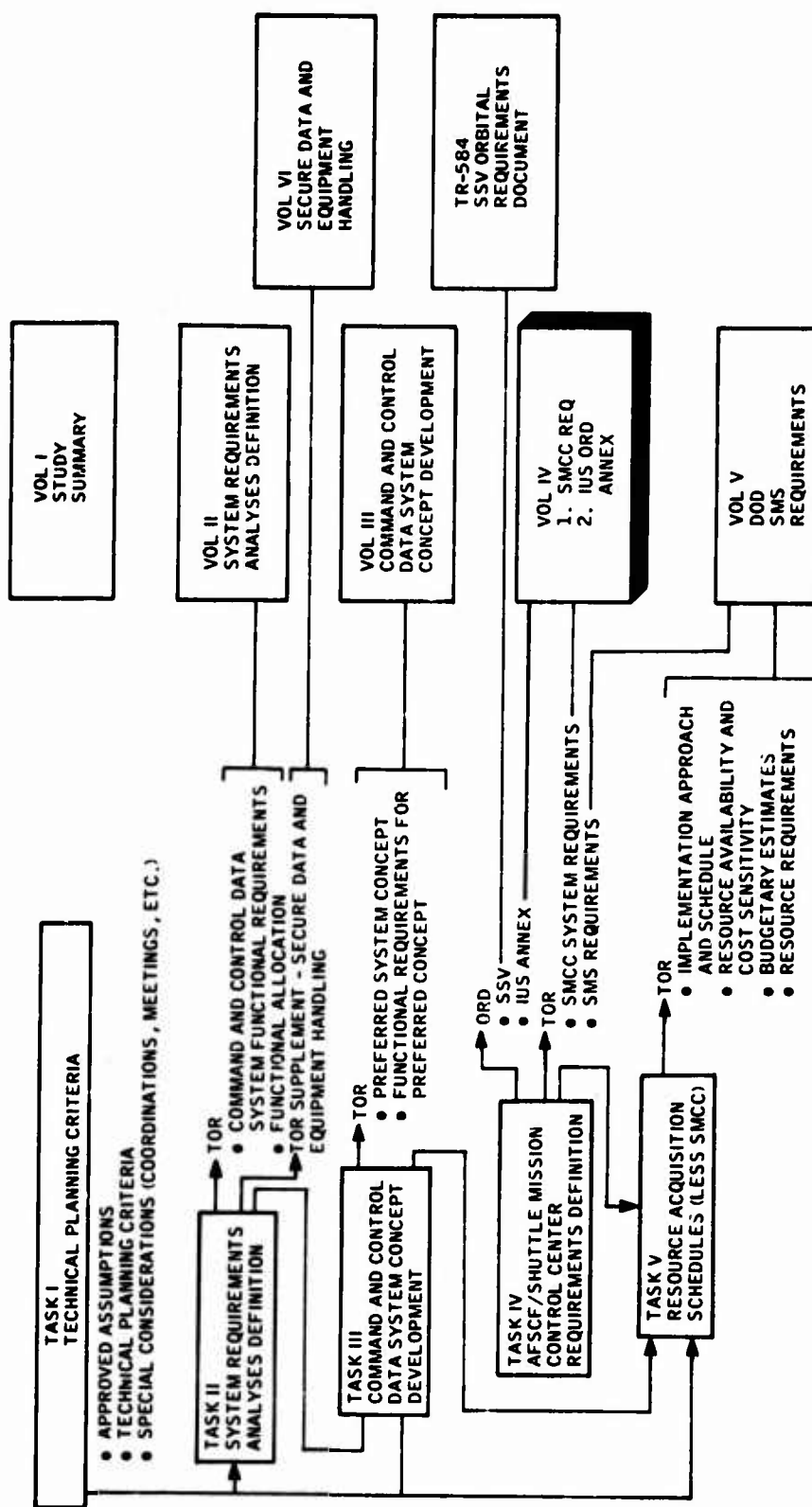


Figure 1 Task Interrelationships

rationale for certain ORD requirements, reasons for some requirements being listed as TBD (to be determined), and discussions of potential SMCC features considered desirable but not mandatory.

Part 2 presents the sample annex for the Space Shuttle Vehicle ORD containing the IUS requirements for SCF support. This is based on the level of detail available at this time. Because of the lack of definition of the IUS, the annex is for information only.

Separate tables of contents for Parts 1 and 2 are provided preceding the text in Part 1 and as paragraph 1.5 of Part 2.

PART 1
SHUTTLE MISSION CONTROL CENTER
REQUIREMENTS ANALYSIS

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SECTION 1

INTRODUCTION

A major output of Task IV of the CCDS study is the *STS Orbital Requirements Document* with Annex 1, *IUS ORD*, which has been published separately as PHO-TR584, 14 September 1974. The purpose of part 2 of this TOR is to supplement the ORD by:

- Discussing topics that influence the ORD but are not topics within it (e.g., estimate of SMCC operating position requirements)
- Explaining rationale or considerations for certain items within the ORD that are TBD.
- Discussing considerations affecting implementation of Control, Display, Data Processing, and SMCC interfaces.

SECTION 2

SMCC REQUIREMENTS

STS flight operations were reviewed to determine the ground functions required of the SMCC. Using as a baseline the functional organization contained in *DOD STS Operations Concept Document* (Draft), dated 6 August 1974, the SMCC support functions were assigned to one or more of the functional groups described in that document. If additional functional groups were required, such groups were added. Analysis of the functions assigned was then accomplished to determine if any functional groups could be combined and to recommend the number of operating positions required within each group.

This section presents the results of those analyses.

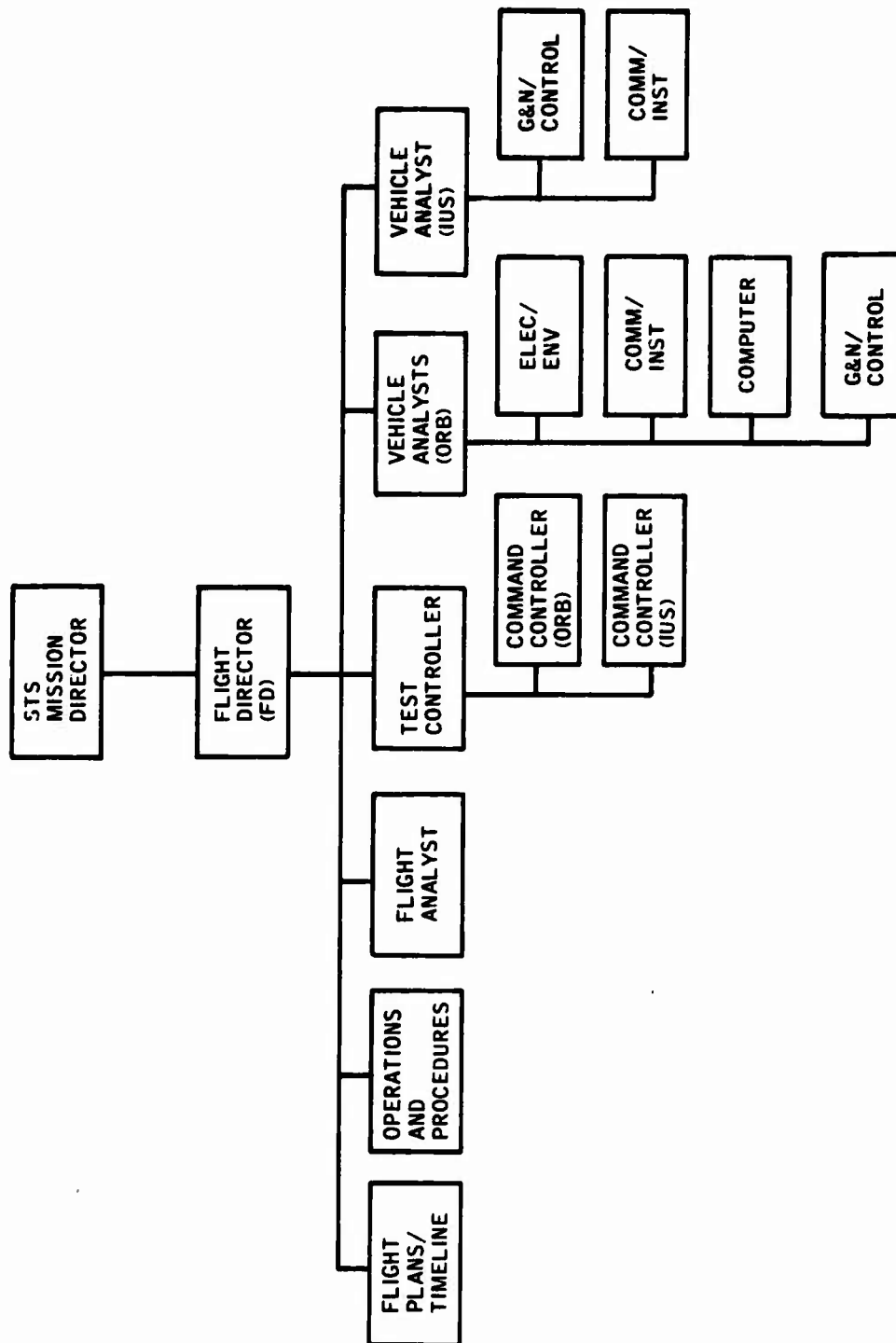
2.1 OPERATING POSITIONS

2.1.1 General. This paragraph presents the recommended SMCC operating positions and for each position, it defines the functions to be performed and the information, control, and voice communication requirements. In defining these requirements two functional SMCC groups are considered: Orbiter and IUS.

Figure 2-1 shows the positions and organization of the SMCC in support of the Orbiter and IUS. Tables 2-1 and 2-2 list the recommended positions, define the activity period (nominal and contingency) for each operating position, and identify the type of console anticipated for each position (i.e., fixed or general-purpose). The fixed console will be used by positions which require continuous or near-continuous manning. The general-purpose console will provide a multifunction operating position.

2.1.2 SMCC Operating Positions

2.1.2.1 STS Mission Director (STSMD). The STSMD will be responsible for the overall control and direction of all STS flights supported from the SMCC. He will receive periodic status reports from SMCC flight director(s) and make mission management decisions based



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Figure 2-1 SMCC Organization for Orbiter and IUS

TABLE 2-1
SMCC SUPPORT MANNING BY POSITION

POSITION	NOMINAL	CONTINGENCY	TYPE CONSOLE
STS MISSION DIRECTOR	X	X	FIXED
FLIGHT DIRECTOR (FD)	X	X	FIXED
TEST CONTROLLER	X	X	FIXED
COMMAND CONTROLLER (ORBITER)		X	FIXED
VEHICLE ANALYST (ORBITER)	X	X	FIXED
ELEC/ENV		X	GP
COMM/INST		X	GP
COMPUTER		X	GP
G&N/CONTROL		X	GP
FLIGHT PLANS/TIMELINE		X	GP
OPERATIONS AND PROCEDURES		X	GP
FLIGHT ANALYST (ORB & IUS)	X	X	FIXED

TABLE 2-2
IUS MANNING BY POSITION

POSITION	PRE-DEP PERIODS		FREE-FLIGHT PERIODS		TYPE CONSOLE
	NOMINAL	CONTINGENCY	NOMINAL	CONT OR HIGH ACTIVITY	
VEHICLE ANALYST (IUS)	X	X	X	X	FIXED
G&N/CONTROL				X	GP
COMM/INST				X	GP
COMMAND CONTROLLER (IUS)			X	X	FIXED

on overall mission and flight crew safety considerations. Primary responsibilities of the STSMD are to:

- Provide overall control and direction of all STS flights
- Disseminate directives of the STS program office to the flight director(s)
- Initiate mission operational redirection based on mission guidelines and objectives
- Initiate flight termination (if required), lengthen or shorten a mission, or redirect Orbiter landing to an alternate landing site
- Ensure that all support activities are being accomplished in a manner that will satisfy flight objectives
- Approve flight plan changes during inflight operations
- Approve changes in mission guidelines, mission rules, procedures, and support requirements
- Evaluate degree of contingencies based on recommendations from supporting positions (flight director) and request additional SCF and/or NASA resources.

Information requirements for the STSMD are:

- Mission timeline/schedule and present activity point along the timeline
- Groundtrack and present Orbiter location
- Next station contact (time and ID)
- Flight plan
- Status (GO/NO-GO) of flight and ground systems
- Time, i.e., Greenwich mean time (GMT), ground elapsed time (GET), and mission elapsed time (MET)

- Next use of Orbiter (time, priority, and location)
- Alternate landing site status (e.g., weather, landing aids)
- Ferry aircraft availability
- New timeline information
- Payload status (GO/NO-GO)
- Relative position (Orbiter, satellite, upper stage and deployment/retrieval points)
- IUS groundtrack/present position
- Event sequences
- Contingency alarm (NO-GO status of Orbiter ground systems)
- Nature of failure, e.g., Guidance and Navigation (G&N) System and trajectory out-of-limits.

2.1.2.2 Flight Director (FD). The FD will be responsible to the STSMD for mission support of a specific Shuttle flight. During nominal mission periods the FD will perform those normal activities associated with the overall coordination and supervision of mission operations. During contingency situations he will be assisted by the Flight Plans/Timeline (paragraph 2.1.2.2,A) and Operations and Procedures (paragraph 2.1.2.2,B). FD responsibilities are:

- Manage SCF operational activities in real-time to ensure satisfactory accomplishment of mission objectives
- Direct/redirect STC elements as required to accomplish mission objectives
- Determine and direct the accomplishment of alternate command plans in real-time
- Implement alternate procedures to ensure program objectives are satisfied
- Primary voice interface with Orbiter

- Provide overall coordination of SCF resources with responsible agencies when conflicts arise
- Coordinate with payload Mission Control Center (MCC) user and STS disciplines in support of mission management decisions
- Maintain status of landing site
- Maintain awareness of mission status (GO/NO-GO for mission events and activities)
- Assist STSMD in determination of contingency manning
- Evaluate degree of contingency and determine need for increased manning when within operational guidelines of the STSMD
- Direct and supervise the implementation of security plans and procedures
- Coordinate the release of all operational communications peculiar to mission support to NASA or other agencies.

Information requirements for the FD are the same as the STSMD plus the following:

- An additional level of payload status data
 - Flight plan changes and projections of impact to user
 - Flight plan variations
 - Mission activity variations
 - RTS support schedule/capabilities
 - Landing site status.
- A. Flight Plans/Timeline. The Flight Planner (FP) will be responsible to the FD for monitoring and updating the mission flight plan during contingency support periods. Primary responsibilities of the FP are to:
- Perform planning, coordination, and implementation of all mission activity changes with STS disciplines

- Provide detailed flight plan development and crew procedures during contingency mission phases to the FD
- Provide summary planning information for optimization of the mission objectives
- Prepare detailed crew procedures and timeline schedules in line with mission objectives and vehicle/crew constraints.

Flight Plans/Timeline information requirements are:

- Flight plan-baseline/updated
- Timeline-baseline/updated
- Crew procedures
- Crew activities schedule/crew equipment
- Time
- Mission rules/objectives
- Event sequence
- Mission resources (Orbiter and crew)
- Groundtrack.

B. Operations and Procedures (O&P). The O&P position will provide support to the FD during contingency periods. Responsibilities of the O&P position are to:

- Coordinate implementation of the contingency mission control procedures
- Coordinate data management timelines
- Coordinate utilization of ground processing and data distribution with other team members and remote control areas (user MCC)
- Coordinate recovery of mission data from remote sites and data storage.

O&P information requirements are:

- Timeline/schedules
- Flight plan
- Next station contact
- Acquisition of signal/loss of signal times
- Station configuration and SMCC system status
- Mission rules/mission objectives
- Groundtrack
- Data source/format
- Time and event sequences.

2.1.2.3 Test Controller (TC). The TC will be responsible to the FD for the overall command and control coordination between the SMCC and the Remote Tracking Station (RTS). Other TC responsibilities are to:

- Supervise the activities of allocated AFSCF resources
- Coordinate with network scheduling for normal and contingency scheduling
- Control voice and data interfaces with RTS's
- Provide prime SMCC secure voice communications interface between the Orbiter and FD
- Monitor transmission of all program data between the Orbiter vehicle and the STC
- Initiate, control, and conduct all prepass, pass, and post-pass briefings with support personnel
- Provide the backup to command and configuration tasks by the command controller
- Coordinate contingency network support with NASA.

Information requirements for the TC include:

- Timeline/schedule
- National Oceanic and Atmospheric Administration (NOAA) weather inputs
- Flight plan
- Next station contact
- Groundtrack
- SMCC System(s) status - GO/NO-GO
- Landing site status
- RTS status/configuration
- RTS support schedule/capabilities
- Space Tracking and Data Network (STDN) support status/capabilities
- Communications plan
- STS tracking/next station contact
- Incoming data status, i.e., data sync and data source (vehicle)
- Time
- Command status/review
- Command flow
- Active uplink site/alternate uplink site
- Command data location
- Acquisition of signal/loss of signal times
- Event sequence.

2.1.2.4 Command Controller (Orbiter). The Command Controller (CC) will be responsible to the TC for the overall status of the SCF command capability for the Orbiter. This position will be manned during contingencies and during periods of activity which require increased ground support. Primary responsibilities of the CC include the following tasks:

- Monitor and control command generation, review, and transfer of real-time commands and command loads
- Monitor and control SCF network command capability
- Monitor command flow through SCF network
- Prepare and recommend changes to the pass plan
- Complete the command prepass checks
- Obtain command summaries.

CC information requirements are:

- Command status/review
- Command flow
- Active uplink site/alternate uplink site
- Command data location - site loads in core
- Flight plan
- Timeline/schedule
- Time
- Command verification/reject status
- Acquisition of signal/loss of signal times
- Groundtrack
- Next station contact
- RTS status/configuration
- Event sequence.

2.1.2.5 Flight Analyst (FA). The FA position provides support to both the IUS and Orbiter during nominal and contingency support periods. Functions of the FA in support of IUS operations are listed in paragraph 2.1.3.3.

The FA will be responsible for the trajectory analysis activities during all phases of the mission including all ascent trajectory monitoring, Terminal Area Energy Management (TAEM), and approach/landing position data. The FA position will monitor and evaluate Orbiter and IUS trajectory and provide trajectory status data to the FD, other SMCC positions, and user MCC's. This status data will permit evaluation of trajectory acceptability and/or permit management decisions on maneuvers required to maintain a nominal mission or replan for an alternate mission.

Primary functions of the FA are to:

- Transmit tracking and commanding prepass tapes and command messages (IUS/Tug)
- Transmit RTS tracking data for Orbiter acquisition and pass support
- Monitor and assist reentry/landing planning operations
- Monitor and control the offline flight support computer scheduling and utilization
- Maintain mission trajectory profile
- Provide GO/NO-GO status of Orbiter trajectory to management
- Analyze trajectory impacts on flight plan
- Participate in mission design replanning
- Analyze trajectory impacts on Orbiter systems
- Update Orbiter ephemeris/state vector (current and desired)

- Predict day/night schedules
- Provide inputs to rendezvous planning
- Monitor and evaluate Orbiter maneuvers.

FA information requirements are:

- NOAA/weather inputs
- Orbital ephemeris/state vector (current and desired)
- Flight plan
- Timeline/schedule
- Target vehicle state vector
- Consumables usage tables/Propulsion System's status
- Station contact schedule
- STS tracking/next station contact
- Sun rise/set schedules
- Acquisition of signal/loss of signal times
- Command verify/reject
- Next station contact
- Time and event sequence
- Groundtrack
- Maneuver tables
- RTS status/configuration.

2.1.2.6 Vehicle Analyst - Orbiter (VAO). The VAO will maintain top-level status of Orbiter systems status and Orbiter configuration during nominal mission activities. Periodic progress reports and mission essential consumables will be maintained by the VAO. Significant changes in system status which require real-time action will be reported to the FD. The VAO will support prepass activities and analyze data resulting from pass or postpass activities.

During contingencies the VAO will be assisted by subsystem personnel. These positions will be manned as required and will provide the VAO with periodic mission progress reports and mission-essential consumables status reports related to: (1) Electrical/Environmental; (2) Communications/Instrumentation; (3) G&N/Control, and (4) Computer Systems. This data will be used to advise the FD of mission progress and as tools in replanning if required.

Primary functions of the VAO are to:

- Maintain top-level status of Orbiter configuration, i.e., vehicle problem analyses and monitor payload/Orbiter interfacing subsystem status
- Analyze flight plan changes impact on Orbiter systems
- Assist mission management in replanning as required.

VAO information requirements are:

- Timeline/schedules
 - Flight plan
 - Orbiter system(s) status - GO/NO-GO and systems data
 - Time and event sequences
 - Consumables tables and maneuver tables
 - Mission rules/mission objectives
 - Command verify/reject
 - Resources (Orbiter, payload, SCF/STDN)
 - Orbiter/target state vector.
- A. Electrical/Environmental. The electrical and environmental position is responsible to the VAO, for analysis of the Orbiter Electrical Power System (EPS) and the Environment Control System (ECS). The position will report GO/NO-GO status based on evaluation of systems performance and trend data. Electrical/Environmental information requirements are:
- Timeline/schedule

- Flight plan
- System telemetry data (batteries, fuel cells, power consumption, power distribution and life support consumables/systems status)
- Time and event sequence.

B. Communications/Instrumentation. The Communications and Instrumentation position is responsible to the VAO for analysis of the Orbiter communications and instrumentation systems. This position will report GO/NO-GO status based on evaluation of systems performance and trend data.

Communications/instrumentation information requirements are:

- Timeline/schedule
- Flight plan
- System(s) telemetry data (communications and instrumentation)
- Time and event sequence.

C. G&N/Control. The G&N/Control position is responsible to the VAO for analysis of the Orbiter G&N and Control Systems. This position will report GO/NO-GO status based on evaluation of systems performance and trend data. Functions of this position are to:

- Monitor and evaluate G&N systems performance
- Evaluate onboard computer information - flight program
- Monitor and evaluate Orbiter Propulsion System's status and trends
- Monitor and evaluate Attitude Control System's status and trends.

G&N/Control information requirements are:

- Timeline/schedule
- Flight plan
- Groundtrack/next station contact
- G&N System telemetry data
- Maneuver tables
- STS tracking/next station contact
- Consumables
- Time and event sequence
- Flight program
- Orbiter state vector
- Target state vector
- Landing coordinates.

D. Computer. The computer position is responsible to the VAO for analysis of the Orbiter Onboard Computer System's performance and status. Primary functions of this position are to:

- Monitor and evaluate onboard computer performance, trends, and configuration
- Provide support for onboard software functions.

Computer position information requirements are:

- Timeline/schedule
- Flight plan

- Orbiter onboard computer telemetry data such as processing allocation, software monitor, and processor management
- Time and event sequence
- Flight program.

2.1.3 Interim Upper Stage (IUS) Operating Positions

2.1.3.1 Command Controller (IUS/Tug). The CCIUS will be responsible to the TC for the SCF command capability for the IUS. He will provide the FD with IUS status data and evaluate new mission requirements impacts. In addition, he will make recommendations for, and evaluate, flight plan changes.

Primary functions of the CCIUS are to:

- Direct command operations at the RTS
- Generate IUS commands for transmission to RTS and uplink to IUS
- Coordinate IUS/satellite operations for satellite deployment and handover involving the IUS
- Maintain overall status of IUS and flight plan variations
- Provide assistance to the FD in mission replanning for areas pertinent to IUS operation
- Verify satellite data integrity during IUS/satellite operations
- Advise the STSMD and the FD of contingency situation and determine or assist in the determination of corrective action.

Information requirements for the CCIUS are:

- Mission timeline and present activity point (Orbiter and IUS)

- Groundtrack and present location (Orbiter and IUS)
- Next station contact (IUS)
- Flight plan
- Status (GO/NO-GO) of flight and ground systems
- Time (GMT, GET, MET)
- New timeline information
- Payload status (GO/NO-GO)
- Relative position (Orbiter, satellite, IUS and deployment/retrieval points)
- Event sequences
- Mission rules, guidelines, and procedures
- Satellite/IUS interface status checks
- Mission planning data (e.g., consumables, consumables trends, maneuver tables, and rendezvous tables)
- System status displays
- Site acquisition tables
- Network status
- Station configuration
- Command status/review (IUS)
- Command flow
- Active uplink site/alternate uplink site.

2.1.3.2 Vehicle Analyst - IUS (VAIUS). The VAIUS position will be responsible for maintaining system status of the IUS during free-flight or providing assistance in contingency situations when the IUS is stowed in the Orbiter payload bay. Some contingency situations may require more detailed analysis of IUS subsystems. During these periods the VAIUS will be assisted by the IUS G&N/Control and Communications/Instrumentation positions.

Primary responsibilities of the VAIUS are to:

- Evaluate proposed flight plan changes for impact to IUS systems
- Monitor and maintain status of IUS systems
- Format and transmit real-time commands and command loads to RTS
- Assist FD in mission planning activities
- Perform IUS malfunction analysis and recommend corrective action.

Information requirements for the VAIUS are:

- Mission timeline and present activity point (Orbiter and IUS)
- Groundtrack and present location (Orbiter and IUS)
- Flight plan
- IUS systems GO/NO-GO status (e.g., sensor, communications, propulsion, instrumentation)
- Time (GMT, GET, MET)
- Additional timeline information and timeline changes
- Payload status (GO/NO-GO)

- Event sequences
 - Mission rules, guidelines and procedures as applied to IUS systems
 - Satellite/IUS interface status checks
 - System tabs (tabular listing of systems data).
- A. G&N Control. The G&N/Control monitor is responsible to the VAIUS for the analysis of IUS G&N, propulsion, attitude control, vehicle sequencing and computer. GO/NO-GO status will be reported based on evaluation of system status and trend data. He will perform malfunction analysis on those systems for which he is responsible and will provide assistance to the VAIUS in the determination of contingency support. The G&N/Control position will be manned during contingency or high activity periods during IUS free-flight.

Information requirements for the G&N/Control are:

- Mission timeline and present activity point (Orbiter and IUS)
- Groundtrack and present location (Orbiter and IUS)
- Flight plan
- Time (GMT, GET, MET)
- Additional timeline information and timeline changes
- IUS/satellite interface status
- Mission rules, guidelines, and procedures
- Event sequences

- Systems tabs and trends to include inertial measurement unit, attitude measuring sensors, attitude control, computer hardware and software, accelerometers, star trackers/horizon sensors, sequential system, main engine, propulsion tank management, consumables utilization, mass management, and structures and thermal control
- Maneuver tables
- Rendezvous tables.

B. Communications/Instrumentation. The Communications/Instrumentation monitor is responsible to the VAIUS for the analysis of the IUS communications, instrumentation, and EPS. GO/NO-GO status will be reported based on evaluation of system status and trend data. He will perform malfunction analysis on those systems for which he is responsible and will provide assistance to the VAIUS in the determination of contingency support. This position will be manned during contingency or high activity periods during IUS free-flight.

Information requirements for the Communications/Instrumentation position are:

- Mission timeline and present activity point (Orbiter and IUS)
- Groundtrack and present location (Orbiter and IUS)
- Flight plan
- Time (GMT, GET, MET)
- Additional timeline information and timeline changes
- IUS/satellite interface status
- Mission rules, guidelines, and procedures
- Event sequences

- System tabs and trends to include power distribution, power consumption, batteries, heaters, radiators, communications systems (e.g., S-band, TV), signal conditioners, command receiver, sensors, and multiplexers.

2.1.3.3 Flight Analyst - IUS (FAIUS). The FAIUS position will be combined with the FAO position. For the IUS the FA will provide support in orbit determination, ephemeris generation, and maneuver planning. In performance of this task he will compare actual trajectory data with desired trajectory and participate in malfunction analysis in contingency situations. Primary functions of the FAIUS are to:

- Assist in mission management decision making which requires IUS trajectory data
- Notify satellite user personnel of changes in IUS orbital state
- Perform IUS maneuver and rendezvous planning activities
- Perform trajectory analysis and make recommendations for corrections to non-nominal trajectory profile
- Prepare and initiate commands and command loads for IUS Orbital state corrections.

Information requirements for the FAIUS are:

- Mission timeline and present activity point (Orbiter and IUS)
- Groundtrack and present location (Orbiter and IUS)
- Flight plan
- IUS systems GO/NO-GO status
- Time (GMT, GET, MET)
- Additional timeline information and timeline changes

- Payload status (GO/NO-GO)
- Event sequences
- Mission rules, guidelines, and procedures
- Maneuver planning tables
- Rendezvous tables
- IUS attitudes
- IUS mass properties
- Trajectory profile (Orbiter & IUS)
- Ephemeris tables (Orbiter & IUS).

2.1.4 Manning. The SMCC operating positions will provide support to both the Orbiter and the IUS. For the Orbiter this support is divided into nominal and contingency. For the IUS this support is divided into stowed operations and free-flight operations; these periods are then further subdivided into nominal and contingency.

2.1.4.1 Orbiter Manning. During nominal support periods the SMCC operating positions to be manned are: STSMD, FD, TC, VAO, and FA-Orbiter. It is anticipated that the STSMD will not be on duty at all times and in his absence the FD will assume his responsibilities. The other positions would be manned at all times.

In Task III it was baselined that the amount of contingency support will be dependent on the mission situation. In determining the manning for contingencies, it is assumed that all contingencies will require higher activity in the areas of Flight Plans/Timeline and Operations and Procedures. Command and control requirements are also anticipated to increase during contingency situations. Thus, these positions (Flight Plans/Timeline, Operations and Procedures, and Command and Control) will be manned for the majority of contingency situations. Other positions are for systems support and will be manned on an as required basis. These positions are Electrical/Environmental, Communications/Instrumentation, G&N/Control and Computer.

2.1.4.2 IUS Manning. During nominal support periods when the IUS is stowed in the payload bay only the VAIUS position will be manned. For nominal periods when the IUS is in free-flight additional support will be provided by the CCIUS position.

For contingency support periods when the IUS is stowed in the payload bay the only IUS support position to be manned is the VAIUS. During contingency or high-activity periods (e.g., payload deployment, midcourse correction planning, and execution) all IUS positions will be manned to include: VAIUS, G&N/Control, Communications/Instrumentation, CCIUS and FAIUS.

2.1.5 Console Utilization. Two types of consoles will be used by SMCC personnel. These are: fixed and general-purpose.

Fixed consoles are provided for the STSMD, FD, TC, CC (Orbiter), VAO, FA (Orbiter), FAIUS, CCIUS and VAIUS.

Fixed consoles will be configured as required for these specific operating positions. Control modules used for command uplink, command enable/disable, and data entry will be provided according to individual console requirements. Each console will be provided a cathode ray tube (CRT) display, display request module, and communications circuits.

General-purpose consoles will be configured for multifunction usage. Generally, these consoles will provide a CRT display device, display request capability, data entry device and communication circuits. General-purpose consoles will provide additional support capability for contingency situations. Six general-purpose consoles will be provided to be used by the Flight Plans/Timeline, Operations and Procedures, Electrical/Environmental, Communications/Instrumentation, G&N/Control and Computer operating positions on an as-required basis. Two additional general-purpose consoles will be provided for contingency support of the IUS.

2.1.6 Control and Voice Communication Requirements. Table 2-3 shows the control and voice communication requirements by position. Control requirements are divided into display request, command uplink, command enable/disable and general data entries. Communication requirements are inter- and intra-center and inter-agency voice communication links.

TABLE 2-3
VOICE COMMUNICATIONS AND CONTROL REQUIREMENTS

POSITION	CONTROL REQUIREMENTS			COMMUNICATIONS (VOICE) REQUIREMENTS												
	DISPLAY REQUEST	COMMAND UPLINK	COMMAND ENABLE/DISABLE	SMCC POSITIONS	JSC/KSC	NOAA	UPPER STAGE POSITIONS	LANDING SITE	GSFC	RANGE	SATELLITE MCC'S	CREW VOICE (MONITOR)	AIR/GROUND	RTS	WEATHER STATION	LAUNCH SITE
STS MISSION DIRECTOR	X			X	X		X	X	X		X	X				X
FLIGHT DIRECTOR (FD)	X			X	X		X	X	X		X	X	X			X
TEST CONTROLLER	X	X	X	X	X		X	X	X	X	X	X	X	X		X
COMMAND CONTROLLER (ORBITER)	X	X		X	X		X	X	X		X	X				X
VEHICLE ANALYST (ORBITER)	X	X		X	X		X	X	X		X	X				X
ELEC/ENV	X			X	X		X	X	X		X	X				X
COMM/INST	X			X	X		X	X	X		X	X				X
COMPUTER	X			X	X		X	X	X		X	X				X
G&N/CONTROL	X			X	X		X	X	X		X	X				X
FLIGHT PLANS/TIMELINE	X			X	X		X	X	X		X	X				X
OPERATIONS AND PROCEDURE	X			X	X		X	X	X		X	X				X
FLIGHT ANALYST (ORBITER & IUS)	X	X		X	X		X	X	X		X	X				X
VEHICLE ANALYST (IUS)	X	X		X	X		X	X	X		X	X				X
G&N/CONTROL	X			X	X		X	X	X		X	X				X
COMM/INST	X			X	X		X	X	X		X	X				X
COMMAND CONTROLLER (IUS)	X	X	X	X	X		X	X	X		X	X		X		X

2.1.7 Information Requirements. Each of the preceding paragraphs describe the information requirements by position in support of the Orbiter and IUS. Tables 2-4 and 2-5 present a summary of these information requirements by position.

TABLE 2-4
INFORMATION REQUIREMENTS BY POSITION (ORBITER)

INFORMATION	STSMO	FD	TC	CC	VAO	ELEC/ENC	COMM/INST	COMPUTER	GAN/CONT	FLIGHT PLANS/ TIMELINE	OPS & PROC	FA (ORBITER)
MISSION TIMELINE/SCHEDULE	X	X	X	X	X	X	X	X	X	X	X	X
GROUND TRACK	X	X	X	X	X	X	X	X	X	X	X	X
NEXT STATION CONTACT	X	X	X	X					X			X
FLIGHT PLAN	X	X	X	X	X	X	X	X	X	X	X	X
GO/NO GO SYSTEM STATUS	X	X	X		X							
TIME	X	X	X	X	X	X	X	X	X	X	X	X
ORBITER NEXT USE	X	X										
ALT LAND SITE STATUS	X	X										
FERRY AIRCRAFT AVAILABILITY	X	X										
NEW TIMELINE INFO	X	X										
GO/NO GO PAYLOAD	X	X										
RELATIVE POSITION	X	X										
IUS GROUND TRACK	X	X										
EVENT SEQUENCE	X	X	X	X	X	X	X	X	X	X	X	X
CONTINGENCY ALARM	X	X										
NATURE OF FAILURE	X	X										
MORE DETAILED PAYLOAD STATUS		X										
FLIGHT PLAN CHANGES		X										
MISSION ACTIVITY CHANGES		X								X		
ACQUISITION/LOSS OF SIGNAL TIMES			X	X							X	X
STATION CONFIGURATION			X	X							X	X
MISSION RULES/GUIDELINES/PROCEDURES	X	X			X	X	X	X	X	X	X	
DATA SOURCE/FORMAT											X	
NOAA/WEATHER			X									X
GO/NO GO SMCC SYSTEMS			X								X	
GO/NO GO NETWORK STATUS												
LANDING SITE STATUS			X									
CREW PROCEDURES										X		
MISSION RESOURCES					X					X		
CONSUMABLES TABLES					X				X			X
SYSTEMS DATA (ORBITER)					X	X	X	X	X			
COMMAND VERIFY/REJECT			X	X								X
MANEUVER TABLES					X				X			X
CREW ACTIVITIES										X		
FLIGHT PROGRAM					X			X	X			
ORBITER STATE VECTOR					X				X			X
TARGET STATE VECTOR					X				X			X
SUN RISE/SET SCHEDULE												X
RTS STATUS/CONFIGURATION			X	X								X
RTS SUPPORT SCHEDULE/CAPABILITIES		X	X									
STDN SUPPORT STATUS/CAPABILITIES			X									
COMMUNICATIONS PLAN			X									
STS TRACKING/NEXT STATION CONTACT			X						X			X
INCOMING DATA STATUS			X									
COMMAND STATUS/REVIEW			X	X								
COMMAND FLOW			X	X								
ACTIVE UPLINK SITE/ALTERNATE UPLINK SITE			X	X								
COMMAND DATA LOCATION			X	X								

TABLE 2-5
INFORMATION REQUIREMENTS BY POSITION (IUS)

INFORMATION	CC (IUS)	VEHICLE ANALYST	G&N/CONTROL	COMM/INST	FLIGHT ANALYST (IUS)
MISSION TIMELINE/SCHEDULE	X	X	X	X	X
GROUND TRACK	X	X	X	X	X
NEXT STATION CONTACT (IUS)	X				
FLIGHT PLAN	X	X	X	X	X
GO/NO GO SYSTEM STATUS (IUS)	X	X			X
TIME	X	X	X	X	X
NEW TIMELINE INFO	X	X	X	X	X
GO/NO GO PAYLOAD STATUS	X	X			X
RELATIVE POSITION	X				X
EVENT SEQUENCE	X	X	X	X	X
MISSION RULES/GUIDELINES/PROCEDURES	X	X	X	X	X
SAT/IUS I/F STATUS CHECKS	X	X	X	X	
MISSION PLANNING DATA	X				X
SYSTEM STATUS DISPLAYS	X	X	X	X	
SITE ACQUISITION TABLES	X				
NETWORK STATUS	X				
DETAILED SYSTEMS DATA (STATUS & TRENDS)		X	X	X	
MANEUVER TABLES			X		X
RENDEZVOUS TABLES			X		X
IUS ATTITUDES					X
IUS MASS PROPERTIES					X
TRAJECTORY PROFILE					X
ORBITER STATE VECTOR					X
IUS STATE VECTOR					X
COMMAND CONFIGURATION	X				
COMMAND STATUS/REVIEW (IUS)	X				
COMMAND FLOW	X				
ACTIVE UPLINK SITE/ALTERNATE UPLINK SITE	X				

2.2 OPERATIONAL CONCEPT

The SMCC is that element from which total mission management and support of the STS flight elements and operations are conducted. During preflight the SMCC will participate in simulations, rehearsals, and systems readiness exercises. During flight phases, the SMCC maintains sufficient cognizance of Orbiter/IUS trajectories, events, systems status, and crew status to exercise overall management of the mission including offline mission replanning. Communications are maintained with other CCDS elements as required.

This paragraph discusses SMCC operations concepts as related to:

- Command generation and initiation
- RTS coordination
- Data entry
- Display requests.

2.2.1 Command Generation and Initiation. Commands will be generated by SMCC software upon request by SMCC operating positions. Types of commands to be generated include real-time commands and command loads. Real-time commands apply to discrete actions such as "recorder dump" or "antenna switching" and would normally be stored premission. Command loads apply to onboard system updates such as "state vector" update and "time" update and require the generation of parameters relative to the type of update. Commands will be generated either by specific requests from an operating position or by a series of interactive actions between the operating position and the command generation software. SMCC operating positions which will be provided command generation capability will be the FA, VAO, VAIUS, CC (Orbiter), CCIUS, and TC.

Command initiation will provide these same operating positions with the capability to initiate a "command uplink" from the SMCC to the Orbiter via the RTS. The initiation of a command uplink will occur after a command is formatted for output to the Orbiter and will require the console operator to perform a specific action such as pushbutton indicator (PBI) depression.

Command enable/disable capability is provided to the TC, CC (Orbiter), and CCIUS. Command enable/disable allows a console position

to be selected for command initiation. During nominal support periods, command enable/disable capability will be performed by the TC. During contingency support periods command enable/disable will be performed by the CC. For IUS commands during IUS free-flight periods command enable/disable capability will be performed by the CCIUS. The implementation of the command enable/disable capability must also consider requirements by the user to format and send commands via the Orbiter when the satellite is under control of the Orbiter.

2.2.2 RTS Coordination. Voice contact will be provided between the SMCC and the RTS prior to pass support, during the pass, and postpass. The FA will perform this function during nominal support periods. Contact prior to the pass will be for the transfer of acquisition and any changes to the pass support plan, and to verify the RTS is configured for Orbiter support. During the pass, coordination will be for the verification of data quality and verification that the pass plan is being implemented. Postpass contacts will be for problem reporting and to make changes in pass support schedules. During contingency situations, the CC position will be manned and this position will coordinate RTS support activities.

2.2.3 Data Entry. Data entry devices will be provided on the general-purpose, VAO, VAIUS, and FA consoles. Entry devices may include alphanumeric keyboards, fixed function keyboards, and programmable function keyboards. These devices will provide operating positions with the capability to request additional information, control computer programs, perform interactive data analysis, and enter general information.

2.2.4 Display Requests. Each console will be provided a display request capability. This capability may be provided through the implementation of a display request module, programmable function module, or alphanumeric keyboard. The display request module would provide only a display request capability. The programmable function module would provide for a display request as well as for other functions such as program control. The alphanumeric keyboard would provide for data entry as well as display request capability.

Displays will be available to SMCC operating positions dependent on mission phase, mission situation (nominal or contingency) and predefined mission requirements. Displays will generally be on formats specified premission with updates to mission-specific parameters according to display requirements.

2.3 DUAL MISSION SUPPORT

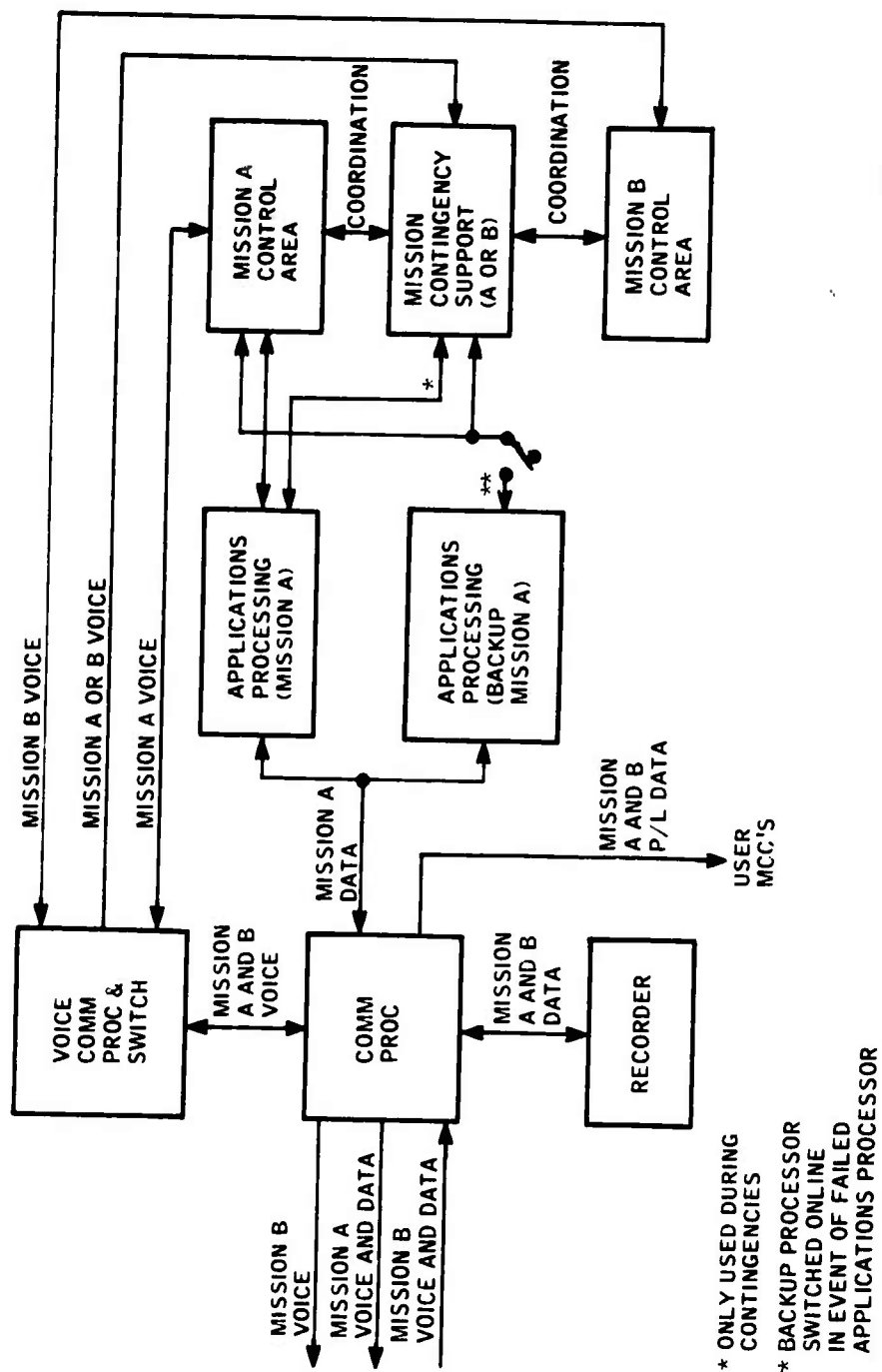
Dual mission support may be required for two Orbiters or for one Orbiter and one Orbiter/IUS/satellite combination requiring simultaneous service. In developing a dual mission operations concept two functional configurations were assumed as candidates. Configuration one (figure 2-2) provides the minimum dual mission support capability required by the DOD guidelines listed below. Configuration two (figure 2-3) provides additional capabilities which are considered desirable for dual mission support.

DOD guidelines provided for dual mission support are that:

- Simultaneous contingency support will not be required
- Single station RTS's will not be shared
- SMCC/AFSCF facilities and hardware are "identical" for purposes of mission support, i.e., neither Orbiter has unique support requirements
- It is operationally unacceptable to "time-share" a console/position; this would jeopardize both mission success and vehicle safety
- Payload data may be required from each Orbiter simultaneously; payload is used here in the broad concept to include upper stages
- Except for voice, only one data stream would be processed at one time
- Handling of digital voice and recording of data will be provided for dual missions.

2.3.1 Configuration 1 for Dual Mission Support. Figure 2-2 presents an SMCC functional configuration (configuration 1) for support of DOD dual missions. For convenience in defining the SMCC support configuration, missions are designated as missions A and B. In this configuration, mission A is the primary mission and mission B is the secondary mission. As applied to this configuration, "primary" refers to the mission for which applications processing is provided as a result of high activity, contingency support, or nominal processing. "Secondary" pertains to the mission for which voice only is being processed and the telemetry data is recorded.

Inputs to the SMCC consist of Orbiter and payload telemetry and voice for both missions. For this configuration the capability



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Figure 2-2 Dual Mission Support Functional Configuration

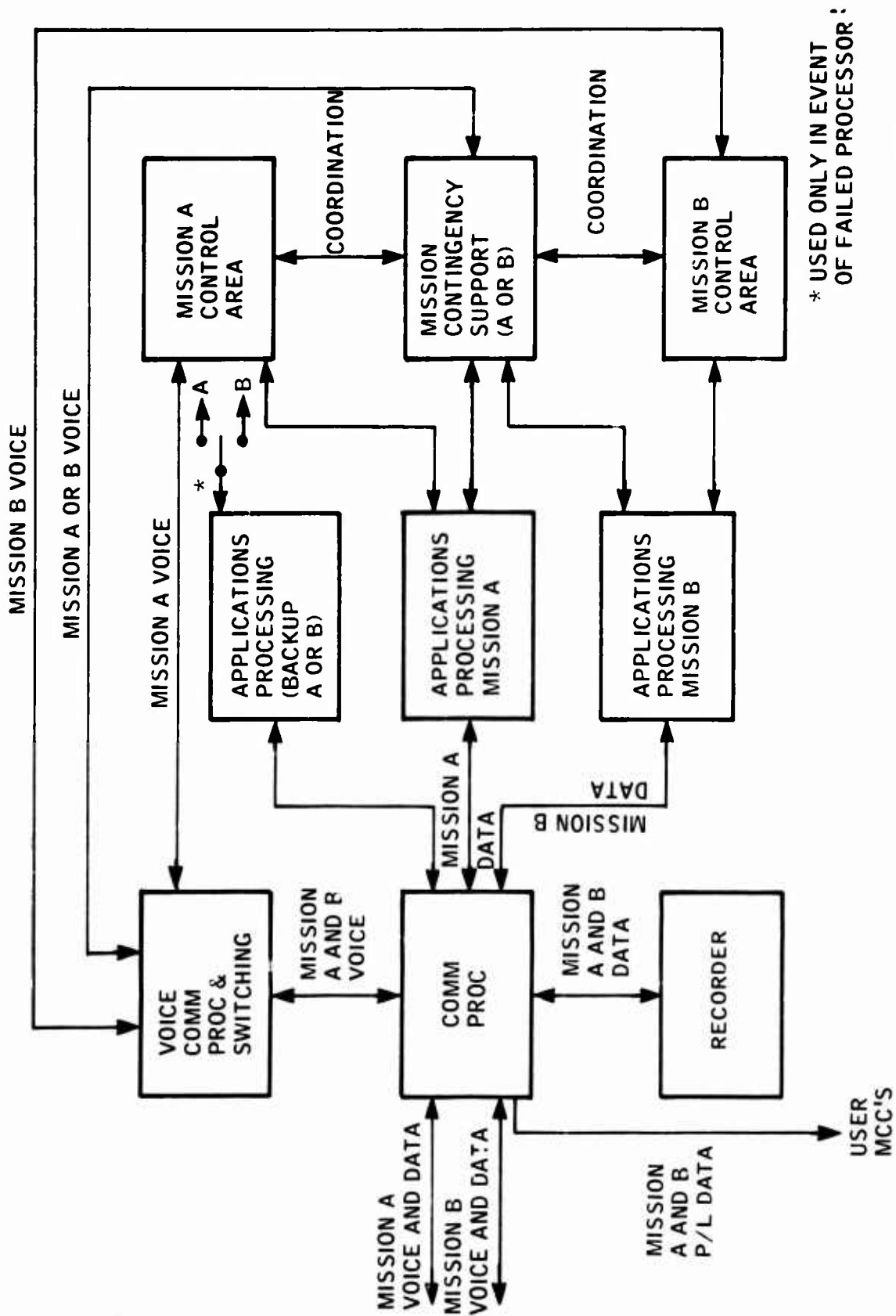


Figure 2-3 Alternate Dual Mission Support Functional Configuration

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is provided for receiving and processing of both downlinks simultaneously. Processing consists of receiving A and B mission inputs and verifying data quality, communications processing, data recording, and stripping out of the digital voice data. Applications processing is provided for the prime mission. Both a prime and backup applications processor are provided for the prime mission. Backup applications processing is provided only during contingency support periods. In addition, payload data from both the prime and secondary mission is routed to the payload data systems for processing and distribution to the user MCC's. Digital voice is processed and routed to the appropriate mission control areas. The capability is provided for voice transmission to/from the separate control areas for both missions. Selective voice monitoring capability of the air-to-ground voice link for either mission from the contingency support area is provided.

Three separate functional areas are provided: mission A control area, mission B control area, and a contingency support area capable of supporting either mission A or B. Coordination voice is provided between the control areas and the contingency support areas. The control areas discussed in this paragraph are functional and need not be implemented as separate facilities or rooms.

Each primary control area (mission A and mission B) is configured with the normal complement of operating positions as defined in paragraph 2.1. These include the FD, TC, VAO, and FA (Orbiter), the VAIUS, and the CCIUS. The STSMD provides overall direction for both missions.

Two Orbiters may have simultaneous contact with the RTS. During these periods, only one mission control area receives real-time data, while the other area views recorded data which is processed on an as required basis. The determination of which control area is to view real-time data is determined by the STSMD based on mission requirements, mission activity, mission status, and mission progress.

Each control area is provided with the capability for voice communications with the Orbiter assigned to their specific mission. Simultaneous processing of Orbiter voice is dependent upon the position of the Orbiters and the RTS scheduling constraints.

In addition, a contingency support area is provided consisting of general-purpose operating positions which may be configured to support multiple functions. Only one mission will be supported in

a contingency mode of operation; the type of contingency will dictate the configuration. Manning of this area is similar to contingency support for a single mission discussed in paragraph 2.2.1. A voice monitor capability is provided for the mission requiring additional support.

2.3.2 Configuration 2 for Alternate Configuration for Dual Mission Support. An alternate support configuration for dual mission is presented in figure 2-3. The addition of a second applications processor in this configuration provides the following additional capabilities:

- Simultaneous applications processing provided for mission A and mission B telemetry inputs to the SMCC and command outputs from the SMCC
- A backup processor provided for support of either mission A or mission B; the backup processor would be online only during contingency situations
- Mission data provided to each mission control area simultaneously in support of its respective mission.

SECTION 3

ORD SUPPLEMENT

3.1 GENERAL

Based on the program requirement that DOD missions will be controlled from the STC, the ORD was prepared listing the preliminary requirements the STS levies on the USAF SCF in support of mission control. However, the agency within the USAF responsible for mission planning and development, flight software development, flight crew training, and similar areas has not been specified. Since this may not be the SCF, the functions were identified in the ORD, but the requirements for them were listed as TBD. As responsibilities for these functions are fixed, analysis to determine the total requirements on the SCF (if applicable) can be conducted.

This section discusses considerations used in determining requirements for the implementing of capabilities or rationale concerned with "TBD" items in the ORD for the major topics of control and display, data processing, SMCC communications, the approach and landing operations, and the ephemeris requirements. Considerations discussed are based on previous experience with control systems and manned spaceflight support and control.

3.2 CONTROL AND DISPLAY CONSIDERATIONS

An SMCC Display/Control System (D/CS) (performing in conjunction with SMCC Data Processing, Communications, Command, and Terminal Systems) is envisioned for providing mission and support personnel the capability of requesting and observing computer-generated data displays. (Refer to section 2.) In this capability, the system will detect, encode, and transmit console-originated operator requests to the computer systems and generate displays in response to these requests, and distribute the display information to the desired display equipment. Related requirements will include provision of a command system permitting user initiation and validation of SMCC computer-resident or computer-generated commands prior to subsequent uplink via RTS.

Based on previous exposure to similar systems, the nominal D/CS will comprise a hardware/software configuration including computer input/output equipment, television and digital event generating and distributing equipment, and console/group display equipment. Primary users of the D/CS will include SMCC operations personnel

(comprising flight controllers, network support personnel, in-flight and postmission analysts, and development/planning groups) which will utilize the system for premission software/hardware development and equipment scheduling. Summary requirements levied on the D/CS by these users (requirements establishing minimum D/CS capabilities) will satisfy the following STS program applications. (Refer also to tables 2-3, 2-4, 2-5, and 2-6):

- STS mission operations (online)
- STS simulations/training
- Postmission data retrieval and analysis
- STS activities scheduling and planning
- STS program development.

Applications involving the operations and inflight mission evaluation groups will include Orbiter-generated and ground-base-computed data, processed and presented in real-time or near-real-time on computer driven D/CS display devices throughout prelaunch, ascent, on-orbit and reentry phases. In addition, postmission evaluation groups will utilize post-operations-processed data displayed in the form of computer-generated reports and plots.

Development/planning group requirements will nominally include displays generated in nonreal-time from ground-base-generated computer inputs, including predefined simulated data and recorded mission data.

3.2.1 Operational STS D/CS Requirements. The interface, distribution, and end device equipment provided by the STS D/CS will satisfy two basic user requirements, display and control, which are defined as follows.

- A. Display. Presentation of data on wall-type projection displays, console-mounted digital readout devices, console-mounted CRT's, hardcopy printers or recorders, microfilm projection equipment, and analog devices.

- B. Control. Provisions of manually operable keyboards, thumb-wheels and/or pushbutton switches as required for access to computer-resident data, control of hardcopy and microfilm facilities, and control of D/CS configurations.

Major D/CS capabilities required for this support include:

- Computer input control
- CRT television generated/distribution
- Group television
- Group display (x-y plotters)
- Digital display (console-mounted event lights)
- Consoles (multifunction desired)
- Telemetry display (event light similar to digital display)
- Support equipment control/display (configuration monitoring/equipment allocation)
- Analog displays.

3.2.1.1 Operational Data Categories. Expected data flow to and from the SMCC user areas will be one or more of the following categories:

- Television display request, presentation, and updates
- Group display request, presentation, and updates
- Program control entry and verification
- Digital event displays/updates
- Analog event displays/updates
- Command entry/verification
- D/CS configuration management data (resource allocation).

3.2.1.2 Multifunction, Programmable D/CS Considerations. Generally, assessments of requirements for the operational data flow categories listed above were performed in light of a traditional central computer-driven display/control environment, wherein major end devices (consoles in particular) are essentially groupings of analog devices and/or transducers directly dependent on the central computer for interpretation or origination of their inputs and outputs, respectively.

However, in recognition of more recent trends toward autonomous, programmable distribution and end devices, each assessment was qualified (where deemed applicable) to note the potential utilization of such techniques. An example would be the assessment of general-purpose consoles capable of satisfying the requirements of several SMCC control positions (refer to Section 2, control positions: Flight Plans/Timeline, Operations and Procedures, Electrical/Environmental, Communications/Instrumentation, G&N/Control). Incorporation of miniprocessing in such consoles with the inherent capability to dynamically reconfigure them in real-time is a typical "multifunction" consideration which will be noted in subsequent paragraphs.

Similar considerations, relative to D/CS data distributors and concentrators, deal with programmable communications controllers; for example, configured to a central computer channel but relieving the host computer of numerous I/O overhead tasks. Major advantages of such configurations are realized particularly in designs where existing processing systems (e.g., existing SCF Digital TV processors) are augmented to accommodate expansion with minimum impact on the existing processor's operating systems software.

3.2.1.3 TV Displays Utilizing a Centralized Computer System

3.2.1.3.1 General Data Flow. A TV display request, for either a console CRT or a projected group TV screen, will originate as a selection at an SMCC user's display request device. The request will be received by computer input multiplexing equipment, formatted into computer-language words and multiplexed into the SMCC data processing equipment. The requested display data is typically

output in computer-language format to SMCC TV distribution equipment for display video generation and routing to the requestor's designated display device.

3.2.1.3.2 End Device Requirements and Considerations. Two general classes of end devices are identified with TV display requirements: display request (input) devices and display presentation (CRT, projection screen) devices.

A. Display Request Devices. Three possible methods to input user display requests are envisioned for the SMCC D/CS. All are presumed for implementation as console-resident devices:

- Interactive terminal keyboards
- Fixed function (PBI) panels
- Programmable (multifunction) panels.

Detailed requirements for each (quantities, locations, electrical specifications) are TBD as noted in the SMCC/STS ORD (paragraph 4.10.6.1.2.1). General considerations necessary in determining those requirements, however, should include:

1. Classes of Data Input. Direct request of preprogrammed display for observation only, and callup of display for editing/modification (program control entries).
2. Required Display Usage and Response Times. Number of frequently used, real-time display requests, compatible with fixed (or programmable) function panels requiring minimum user-computer interaction for callup, vs number of infrequently used, non-real-time display requests more compatible with interactive keyboard entry technique.
3. Flexibility of Display Control Required by Multiple Users. Used on general-purpose consoles. Related considerations should deal primarily with programmable display request panels which are dynamically reconfigurable either from a central processor or from a console-resident miniprocessor (refer to paragraph 3.2.1.3.4).

4. Interface Characteristics. Address codes, function codes, data formats multiplexing compatibility, and physical characteristics (signal level, noise suppression techniques, etc.).

B. Display Presentation Devices. Two methods of displaying TV data were considered for the SMCC D/CS: console-mounted CRT's and group TV (projection TV and/or overhead monitors). Detailed specifications for each are TBD as noted in the ORD. These specifications will, however, reflect as a minimum the following typical considerations:

1. CRT devices

- Quantity and location
- Number of selectable channels
- Refresh rates
- Refresh memory location (computer self-contained part of distributors/video switchers)
- Resolution
- Scanning parameters
- Character size
- Alphanumeric/graphic capabilities
- Vector generation capability (if contained within CRT unit).

2. Projection TV devices

- Quantity and location of projection screens
- Image size(s)
- Type and number of rear projectors
- Optical throw distances

- Projector scanning parameters
 - Resolution
 - Interface characteristics.
3. Overhead TV Monitors. Considerations will be similar to CRT's above, with added consideration for tilt angles, limited display capability (e.g., due to limited resolution) ambient lighting levels, etc.

3.2.1.3.3 TV Data System Distributor/Concentrator Considerations

- A. Display Request Multiplexers/Input Concentrators. In a central computer-oriented D/CS, display requests or display control entries are traditionally multiplexed from multiple console-mounted devices onto the computer I/O channel. It uses intermediate equipment to accomplish the multiplexing and related format conversion (e.g., keyboard bilevels-to-computer language) and signal characteristics conversion (levels, rise times, etc.). As noted in the ORD, detailed requirements relative to this equipment are TBD. System considerations necessary to determine those requirements will include the following:
1. Number of input (display request) devices to be serviced.
 2. Required response time to user-related considerations; for example, required multiplexing speeds, multiplexer buffering requirements, priority request requirements, and computer channel data rate requirements.
 3. Resource allocation such as priority switching of multiplexing capabilities to critical users via program control or manual control.
 4. Critical path availability, such as redundancy, reliability, automatic failover to backup channels, etc., particularly for real-time users.
 5. Interface characteristics, such as computer channel data handling conventions and electrical interface specifications.

B. TV Data Distribution. Determination of distribution requirements for TV data will nominally involve the following considerations:

- Computer language-to-video conversion techniques
- Routing and video switching techniques
- Quantity and quality of output video channels required
- Resource allocation control, such as remote manually or switchable program-controlled allocation of channels to various users
- General interface characteristics, such as computer channel data handling conventions, electrical interface characteristics, refresh/update rates, etc.

3.2.1.3.4 Assessment of Multifunction TV System Capabilities

A. Miniprocessors in Consoles. Determination of actual user end device (CRT, display request input) implementation should reflect the assessment of capabilities realized from data processing contained within the user's console, (e.g., miniprocessors). Two particular considerations should include the following:

1. Reconfiguration Flexibility. In instances where a given general-purpose console may serve multiple users (non-simultaneously), rapid reconfiguration of the console would be desirable. A nominal method for implementing this capability would be to provide essentially "blank legend" consoles with self-contained applications software (selectable by the user via keyboard function code entry) driving the console's legends, event lights, etc., in correspondence to the desired support function.
2. Offline Development Compatibility. Residence of display applications software within a user's console inherently reduces his requirement for online display/request/generation transactions with centralized computer systems (a feature which not only increases his own response

time but more desirably, reduces time-consuming I/O overhead in the central system). For offline program development (mission planning, simulations, program development) this feature could prove quite feasible. A particular advantage can be seen if the SMCC D/CS data processing capabilities were implemented as an augmentation of the existing STC; i.e., any new unique interface handling software, applications handling, etc., could possibly be assumed to a large extent by the console-resident software. *Note: For fixed function consoles (section 2) programmable console features do not appear to have equivalent advantages, but do merit similar consideration.*

- B. Programmable Data Concentrators/Distributors. A requirement of traditional TV distribution systems (distributors/concentrators) is to provide compatibility with computer channel data handling conventions (access method functions, transmission control functions), in addition to performing computer-language-to-video conversion, multiplexing display request inputs, etc. A major constraint associated with the computer interface is the I/O line handling responsibility assumed by the computer's access method software. Programmable I/O controllers (divorced from total dependence on the computer's access software, and implemented as part of the D/CS distribution) appear to be one method of relieving such constraints, and should be considered in determining detailed SMCC D/CS requirements. Desirable features of these controllers would include the following.
1. Flexibility. A given controller can be programmed to interface distribution systems other than TV (e.g., digital event distribution) on a time-shared basis, resulting in decreased numbers of dedicated (fixed-function by hardware) controllers for each type of data distribution. Variable scan rates and formats are related features.
 2. Reduction of Central Processing Unit (CPU) I/O Overhead. Programmable I/O controllers nominally assume the line handling responsibilities between the computer and the display network, relieving the computer of this high overhead requirement.

3. Compatibility with Augmented Systems. In the case where an existing system (e.g., SCF) would be augmented to incorporate a new system (e.g., SMCC D/CS), the capability to program the "existing-computer-to-new system" interface using standalone programmable controllers offers distinct advantages; the major one is reduction in modifications to existing I/O software. This advantage should be evaluated in final determination of the D/CS requirements.

3.2.1.3.5 TV Display Hardcopy Considerations. SMCC personnel viewing a TV monitor display or projection TV display typically desire the capability to hardcopy to given display by initiating a hardcopy request from their console. Nominally, the identity and location of the requestor will be transmitted with the input request to hardcopy control circuits, as switching/routing control data. Subsequent switching of the desired video channel to hardcopy recorder equipment will accomplish the required image conversion. In addition to the requested display data, the resulting hardcopy also includes time-tagging, superimposed on the print. Specific hardcopy requirements are TBD as noted in the ORD, (paragraph 4.10.6.1.2.2). Typical assessments or considerations to be made in determining those requirements will include the following.

- Type of Hardcopy Medium, e.g., thermic or electrolytic photographic ink jet, direct pen, electrostatic, line printer
- Resolution
- Quantity and Access Methods
- Interfaces, e.g., console, computer channel, video converter, video channel switcher, etc.
- Methods of Output Distribution, e.g., pneumatic tube, hand-carry.

3.2.1.3.6 TV Display Program Development. Refer to paragraph 3.2.

3.2.1.4 Group Display Considerations. Large-screen projection plotting and X-Y plotters are the two categories of group displays

envisioned for the SMCC. Detailed requirements for each are TBD as noted in the ORD; general considerations are discussed in the following paragraphs.

3.2.1.4.1 Projection Plots. Large-screen projection plotting displays nominally originate as selections from operator's consoles. The selection data is converted to computer-language format and multiplexed into the computing facilities. The computer(s) output the associated preprogrammed display data in computer-language format to plotting display data distribution equipment. Subsequent display/control processing includes conversion of the computer-language data to control/distribution data for routing to plotting display equipment. Plotting equipment (nominally analog) generates the display in a manner suitable for projection onto large display screens in the designated area(s). Following initial activation of the display, any preprogrammed updates are nominally output from the computer to the group display equipment without operator intervention.

Requirements considerations for this display capability will include:

- A. Input Request Multiplexing/Data Concentration. Considerations will be similar to those specified for TV display requests in paragraph 3.2.1.3.3; i.e., multiplexing, re-formatting (console input-to-computer language, electrical interface compatibility, etc.).
- B. Output Distribution. Output distribution of projection plotting data will require assessment computer-language-to-analog plotting data conversion, address routing decoding, electrical interface compatibility, and ultimate presentation on plotting screens.
- C. End Devices. Methods for, and consideration of, projection plot request devices will be similar or identical to those candidates envisioned for TV display requests defined in paragraph 3.2.1.3.2 (i.e., interactive terminal, fixed function keyboard, programmable function panel, etc.). An exception may be preprogrammed plots which are automatically displayed and updated in real-time in certain mission phases (e.g., trajectory plots).

Requirements for the plotting display presentation will be determined from the following (typical) considerations:

- Screen size(s) and quantities
- Number and type of scribing projectors required
- Static background projection requirements
- Symbol generation requirements
- Control electronics.

3.2.1.4.2 X-Y Plotboard Displays. X-Y plotboards in the SMCC are envisioned for presenting trajectory plotting data received in downlink telemetry data and processed in a preprogrammed sequence for presentation. SMCC display/control processing for X-Y plotting will include real-time interpretation of the telemetry parameters, with subsequent generation and output of the X-Y data in computer-language format to required distribution equipment.

Detailed X-Y plotting requirements will be determined from the following (typical) considerations:

- Plotboard quantities, types, and locations
- Amount of downlink telemetry data to be displayed
- Display formats required
- Computer language-to-analog plotboard value conversion techniques
- Manual control (if required; nominally these plots are generated in a preprogrammed manner with no operator intervention).

3.2.1.5 Program Control Entry/Verification. Program control entry considerations for the SMCC D/CS encompassed the following user entry functions:

- Display Request. CRT, group display

- Command Control. Set up, enable/disable/transmit
- Program Modification. Display callup for edit/modification, program development (nominally offline)
- Console Reconfiguration. If performed by software, these entries could be to either a central processor or a console resident miniprocessor.

Entries will originate at operator's consoles in SMCC user areas. The data will nominally be converted to computer language and multiplexed into the SMCC computers. The computer will verify an entry by illuminating an event light(s) at the position from which original entry was made. The data flow for this process will require the computer to output computer language data to digital display distributors for decoding the desired input location and activating the corresponding digital verification display.

3.2.1.5.1 Entry Device Considerations. The types of devices considered for program control entry are those listed previously for TV and group display request, including:

- Interactive terminal keyboard
 - Fixed function PBI panel
 - Programmable function PBI panel.
- A. Interactive Terminal Keyboards. An interactive (with computer) keyboard is envisioned for many console positions in the SMCC. Detailed requirements are TBD as noted in the ORD. However, general considerations for determining these requirements will include:
- Cursor controls
 - Alphanumeric entry requirements
 - Graphic control requirements
 - Special function codes
 - Special CRT display editing controls, such as erase line, erase page, delete, insert, etc.
 - Light-pen/cursor compatibility

- Interfaces such as CRT, central computer, local computer (miniprocessor), direct closed-loop to console event lights.

These typical considerations are relative to the keyboard device itself. Related major considerations are provision of interactive terminal processing software in the central computer(s), (refer to paragraph 3.2) and any special terminal communications data concentrators required between the central computer and the keyboards.

For applications involving console-resident software (miniprocessor), considerations must deal primarily with keyboard interface software, related console event-light software (e.g., keyboard entry verification) and CRT display generation response to keyboard entries.

- B. Fixed Function Panels. Fixed function panels envisioned for the SMCC D/CS will be console-mounted PBI (pushbutton-indicators) or event light (illumination only) arrays. The fixed function designation refers to the fact that a given PBI or event light provides one and only one function (input or event indication) for any user, as opposed to a programmable panel, whose input or output function may be modified dynamically under software control (refer to paragraph 3.2.1.5.1,C).

General design considerations relative to fixed function panels will include (typically):

- Number of fixed entry parameters required
- Number of fixed event indications required
- Interfaces within the console, to external data concentrators, or to distributors
- Program development requirements (refer to paragraph 3.2).

- C. Programmable Function Panels. While the CRT's/keyboard are considered the primary means of display and control at a console, and may be all that is required in many fixed console applications, "programmable function panels" may be a desirable supplement to them, particularly in the case of

general-purpose consoles. Their use will be determined by the operator and controlled by his application programs.

These panels are normally conceived as "blank legend" event light or PBI panels; each panel's function is determined by either local (console-resident processor) or remoted central processor software. Their utilization requires an operator setup entry (e.g., via an associated console keyboard or fixed function panel) to select and activate the required functional software.

Considerations which will determine detailed requirements for these panels will include utilization of consoles (general-purpose in particular). These considerations must deal with needs for rapid reconfiguration of and functional flexibility of various console panels. If determined to be a desirable feature, the following considerations must be undertaken.

- Alphanumeric capabilities
- Response times
- Program location and complexity
- Special effects (blinking, scrolling)
- Program setup techniques
- Physical properties such as size, quantities, and locations.

3.2.1.6 Digital Event Displays. Digital event display data (event lights) activated on occurrence of preprogrammed events normally occurs without operator intervention. Detailed requirements for generation and routing of those preprogrammed, automatically invoked displays are TBD as noted in the ORD. Determination of those requirements will, however, necessitate the following considerations.

3.2.1.6.1 Distribution Considerations. Digital events may originate either in a console-resident or central computer processor. In the latter case, distribution requirements will be concerned with computer-language-to-analog device activation signals (lamp driver voltage conversion, address routing decoding, and distribution of event light power to the required end device). Associated design

considerations will include redundancy for critical event paths and programmable distributor applications (refer to paragraph 3.2.1.3.3).

For those digital event indications emanating from console-resident miniprocessors (if applicable), distribution requirements would be reduced significantly in that they would be limited to "design considerations within-the-console" in most cases, wherein reduced decode, conversion, and driver design problems are obvious.

3.2.1.6.2 Digital Event End Device. Actual digital event indications nominally occur as illuminations of some end device on a console or group display. For console event indications, the fixed function or programmable function panels previously mentioned will in most likelihood be used. Considerations relative to determining their detailed requirements (noted as TBD in ORD) are the same as for the panels themselves, i.e., alphanumeric capabilities, rear-projection back-lighting, light emitting diodes (LED's), update rates, etc.

3.2.1.7 Analog Event Display/Control. The D/CS is envisioned as requiring analog displays presented on analog stripchart recorders and bilevel event recorders.

3.2.1.7.1 Analog Stripchart Recorders. Analog stripchart recorders are normally utilized as a primary means of displaying control position and vehicle response data. In addition, the recorders may be required for recording selected Orbiter systems data. Detailed requirements for the stripchart recorders are TBD as noted in the ORD. Those requirements will be established from considerations including:

- Number of events to be stripped from the downlink telemetry streams and the associated processing requirements for conversion from digital-to-analog
- Trace amplitudes
- Number of recorder channels/per unit
- Quantity/location of recorder.

3.2.1.7.2 Bilevel Event Recorders. Bilevel event recording equipment consists of fixed still information recording on moving charts, and are generally used for recording of bilevel

engineering events and for biomedical parameters stripped from the telemetry downlink. Detailed requirements are TBD as noted in the ORD. Considerations relative to determining those requirements will include:

- Signal resolution
- Chart speeds/regulation
- Interfaces, [i.e., telemetry ground stations and digital-to-analog converters (DAC's)]
- Locations/quantities.

3.2.1.8 Command Control Entry/Verification Considerations. Command control entries are envisioned for the SMCC D/CS as switch closures originating at SMCC user's consoles. The switch closure signals will be received by computer input multiplexing equipment, formatted into computer language, and multiplexed into the SMCC computers. Subsequent action by the computer programs will extract the selected command from predefined storage and output it to a predesignated remote site.

Verification of command entries will require computer language data containing the identity of the originating location to be output by the SMCC computer to distribution equipment for decoding and activation of an appropriate digital display driver, completing the entry verification by lamp illumination (event light).

Requirements for command control systems in the SMCC D/CS will be derived from the following considerations.

3.2.1.8.1 End Devices (Input and Verification). These considerations are essentially the same as those defined for program control and event indication devices in paragraphs 3.2.1.5 and 3.2.1.6.

3.2.1.8.2 Command Data Processing. Major considerations for command control requirements determinations will be the data flow processes associated with their generation and execution. These considerations, discussed in paragraph 3.5, are summarized here to emphasize their implications relative to D/CS.

- A. Command Generation Processing. The command generator should be responsive to both manual and automatic requests (where indicated).

- Generates command data updates for transmission to the RTS
- Formats data into blocks identified by site and transfers data to the prepass data file
- Recognizes designated levels of constraint violation and responds according to mission rules
- Provides indications, as prescribed, during the command generation process
- Sets the real-time update flag, if there is a need to generate commands for a station during vehicle contact.

B. Command Execute/Modify/Review Processing. Command execute/modify/review programs should provide for the direct up-link of commands to the Orbiter from the SMCC flight and mission controllers. These programs should include the following functions:

- Provide for online inputs from the controllers to allow execution and review of the scheduled commands
- Execute a real-time modified command (modified after the prepass command load update) in place of the prepass updated command
- Recall commands in the currently scheduled RTS command load for review, or display a log of the commands transmitted to the RTS
- Format, by command execute subprograms, the RTS command index number of the real-time modified command with the site ID, and set command message ready flag for the communications subprogram.
- Display the command execute status to the controller who executed the current command when the communications subprogram transmits the command to the site (the command capability is distributed to a number of controllers, in line with their functional responsibility)
- Display the Orbiter command action status to the appropriate controller upon receipt of a command validate message from the RTS, or indication of an excess response time interrupt

- Record a history of the command and status of the response (by the command execute subprogram).

3.2.1.9 D/CS Configuration Management/Equipment Support Considerations. SMCC D/CS equipment will, based on knowledge of existing systems, require configuration control, maintenance and performance evaluation elements. The support requirements determining their scope and complexity will reflect consideration of the following support functions:

- Monitoring computer system selection (online to backup) as related to D/CS equipment
- Performing maintenance functions on D/CS equipment while maintaining predefined systems availability
- Monitoring (within certain critical areas of the D/CS transmission errors, data dropouts, and data loss conditions
- Manually assigning components and/or selection to redundant components, where provided, to enhance system reliability.

3.3 DATA PROCESSING

3.3.1 Minimum Requirements. Data processing discussed in this paragraph represents a basic core of minimum capabilities required by the STC to satisfy STS monitor and support functions. These requirements have been derived from implied or directly stated requirements, or are considered logical extensions of those discussed in current STS requirements documents.

The detailed requirements of the software capabilities described below are defined in the STS ORD, paragraph 4.13.

- A. Front-End Software. Software is required to identify the source of data inputs (Orbiter, satellite and/or IUS), and the type of data (commands, telemetry) and pass the data to appropriate processor modules. This software may also perform data conversion/calibration, input message validation, and interface message formatting prior to routing inputs to other processors.
- B. Data Base Management. Software is required for data base definition, security, storage, retrieval, maintenance, and interface message processing with data input application programs.
- C. Displays. Software is required to provide both requestable and forced console CRT displays. Both alphanumeric and graphic display capabilities are required to satisfy nominal mission status monitoring and contingency support requirements. Required capabilities include software for construction and storage of display skeletons, display request recognition/interpretation, display retrieval and console routing, dynamic data updating of selected displays, and a paging capability for multipage displays.
- D. Limit Sensing/Alarm Generation. Software is required to perform limit-sensing of critical vehicle and crew health status parameters. Required capabilities shall include recognition of candidate parameters upon data receipt, comparison of values received with predefined value ranges, maintenance of bad value counts to determine an out-of-range condition, forced message make-up and appropriate console address(es) routing, and interface with display software to pass/clear forced alarm messages.

- E. Keyboard Processor. Software is required to process console keyboard inputs for display and function execution requests. Required capabilities shall include request validation, input error message generation, display retrieval, function execution request linkage with appropriate application software and display/function output console routing. Additional requirements include keyboard capabilities to freeze (and release) dynamic data updating of a presented display, acknowledge forced caution and warning (C&W) displays, selectively modify initialized parameter constants presented in CRT displays, suppress C&W alarm routing to a specified console position, display keyboard inputs in a CRT reserved "scratch pad" area, and modify/correct displayed keyboard inputs anytime prior to request completion.
- F. Commands Generation. Software is required for command selection, construction, and transmission through a specified RTS. Requirements include capabilities to construct, store, and selectively retrieve both "canned" commands and command "shells." Keyboard and CRT display interface aids are required for command selection and to provide a means whereby variable parameter data may be input to complete construction of command shells.
- G. Peripheral Processors. Software is required for access to the peripheral devices' I/O services. Device handlers are required for input processing from card reader and magnetic tape units, and to direct outputs to card punch, line printer, and magnetic tape units.
- H. Miscellaneous Functions
1. Time Display. Software is required for dynamic display presentation of both GMT and GET. The SMCC time displays shall be updated once per second to reflect both GMT and GET times in hours, minutes, and seconds.
 2. Mission Replanning. This software is required to support contingency situations which necessitate changes to initialized mission planning data. This function shall be invoked as a background application upon console keyboard request and shall include keyboard/display software capabilities necessary to selectively modify/recalculate any mission planning parameter(s).

3. Trend/Analysis. This function provides the capability to project/predict specific subsystem parameter values based on current or history value inputs and rate of consumption/degradation over a specified timeframe. This function would be library-resident and invoked for background execution upon keyboard request from an authorized console position. A series of displays and keyboard actions shall provide capabilities to specify/select parameter and time value inputs and present resultant data in CRT displays. (Data results may prove useful as inputs to the mission replanning functions.)
4. Log/Delog. This utility is especially useful as a debug aid during system development and checkout. The utility can also be used as a personnel training aid or for selective recording and processing of data of peculiar interest during a mission. Selective data/console action logging shall be invoked and terminated by a computer operator upon direction from authorized mission personnel. The delog utility is required for processing and line printer output generation of all or a selected portion of logged data. Logging shall execute as a background application in the online computer system. The delog utility shall execute as a batch program in either an offline computer or the online system, based on availability of required system resources.
5. Data Reduction/Statistics. Software is required to provide (TBD) statistics and summary report outputs on specified parameter data. This software shall consist of a pool of selectable data reduction routines which execute as batch processors. Required mission data base dumps shall be loaded into a "history" data base which then serves as the data source for processing by selected statistics/summary output routines.
6. Performance Evaluation. Software is required for data collection and report generation of system performance statistics. Data collection of selected parameters (e.g., CPU utilization, idle time, I/O channel utilization, etc.) shall be performed in background and output to a system log tape. Report generation software shall execute as a batch processor and present report outputs of logged data on the line printer.

3.3.2 Optional Capabilities. Although not categorized as firm requirements, the following capabilities are considered highly desirable to augment those defined in paragraph 3.3.1.

- A. COM. Computer Output to Microfilm (COM) systems are extremely useful in any system designed to process large amounts of data. Today's COM systems typically accept a variety of data input formats with minimal restrictions as to data block sizes, special COM control characters, etc. A COM system, together with microfilm/microfiche viewers/hardcopiers, provides data output storage condensation and a means by which multiple copies of outputs can easily be obtained whenever required.
- B. Tape Indexing. A tape indexing system is extremely useful, if not a necessity, in any system which requires a sizable magnetic tape library for retention of data. A tape indexing system provides a means by which the appropriate (set of) magnetic tape(s) containing data of interest can quickly be retrieved. This capability is basically a software routine which extracts required descriptive information from data tapes and produces a report output correlating data descriptions with assigned reel numbers. (A report on data base dump tapes, for example, may consist of an ordered list with data base number/name, dump date/time, data start/stop frames, and magnetic tape reel number for each tape processed.)
- C. Checkpoint. The need for a checkpoint capability is primarily based on recovery requirements in the event that a hardware failure results in an unrecoverable loss of mission data bases. This capability is probably *not* required if the following statements are valid:
 - 1. Periodic dumps of critical mission data bases to magnetic tape are scheduled throughout a given mission.
 - 2. In the event of a hardware failure of this type, critical data bases can be reconstructed from dump tape in a reasonably short amount of time (e.g., 30 minutes or less).
 - 3. An unsuccessful recovery (data base reload) attempt will not jeopardize the success of a mission.

If the above statements are invalid, a checkpoint capability may become a firm requirement. The capability primarily consists of a disk-to-disk copy utility which permits rapid failure recovery through replacement of a "destroyed" disk with its most recent copy.

3.4 APPROACH AND LANDING

The active role of the mission agent during the landing operations and the landing site/MCC interaction are not clearly defined at the program level; hence the reason for the "TBD's" in the STS ORD, paragraph 4.5, "Approach and Landing Requirements," concerning landing site/SCF coordination and TAEM assistance.

The objective of TAEM is to place the Orbiter in a favorable position to intercept the final landing approach plane at the correct altitude and speed, and the start of TAEM is the final decision point for choosing the direction of landing. The Orbiter will have the capability to autonomously perform navigation during entry and landing, but it is a NASA Level II requirement (Vol. 18, JSC 07700, paragraph 3.4.11) that the mission operations computers provide the capability to perform backup navigation for the Orbiter during that period and the capability to uplink ephemeris data as required to assure that safe landing approach conditions are achieved. Only when the specific onboard functions for performing TAEM have been defined can the SMCC requirements for backup TAEM assistance be specified.

Another area of concern is the mission control-landing area operations and coordination associated with the approach and landing operations. Although Level I and II requirements are clear that the mission agent, through the MCC or SMCC, retains control of the mission until the Orbiter comes to a stop on the runway, the responsibilities of the personnel at the Landing Operations Area (LOA) are not clear. For example, the *KSC Station Set Requirements Document*, Vol. 17, "Landing," 19 July 1974 states, "The personnel responsible for Orbiter landing operations at KSC will be located at consoles in the LOA." One such console is for the KSC Landing Operations Director. Since VAFB STS systems and procedures will be adapted from the KSC Shuttle ground systems and procedures, it is highly likely that there will be a VAFB Landing Operations Director. His functions must be defined before the SCF requirements to support approach and landing can be specified for VAFB landings of either DOD or NASA flights. Similarly, the KSC Landing Operations Director functions must also be defined before the SCF requirements in support of KSC landings of DOD flights can be specified.

3.5 EPHEMERIS

Ephemeris requirements contained in paragraph 4.8 of the STS ORD do not specify the accuracies required, the time intervals for the ephemeris, or the coordinate system to be used. In addition, the ephemeris is extended to include the Orbiter's expected position vector and velocity during atmospheric flight (until start of TAEM).

The extension of the ephemeris for this program is required to acquire the Orbiter subsequent to blackout in order to provide backup navigation and landing assistance and voice communications between the SMCC and the Orbiter crew.

Ephemeris interval and accuracy requirements are expected to evolve as the program develops, the test programs are conducted, and the results are evaluated.

A standard set of coordinate systems for the Space Shuttle is to be established. This set will comprise the minimal number of coordinate systems required for the practical exchange of data. Currently, NASA in JSC Internal Note No. 74-FM-15, *Candidate Coordinate Systems for the Space Shuttle Program*, lists a set of 26 candidate coordinate systems and states the final set will be developed in this calendar year and recommended as the standard set of coordinate systems for the Shuttle program.

ACRONYMS AND ABBREVIATIONS

A/C	aircraft
AFSCF	Air Force Satellite Control Facility
ALT	Approach Landing Test
ATP	Acceptance Test Procedure
C&W	caution and warning
CAPCOM	spacecraft communicator
CC	Command Controller
CCATS	Command, Communications, and Telemetry System
CCDS	Command and Control Data System
CCIOUS	Command Controller-interim upper stage
CDE	Central Data Element
CDR	Critical Design Review
C/O	checkout
COM	Computer Output to Microfilm
CPU	central processing unit
CRT	cathode ray tube
CY	calendar year
DAC	digital-to-analog converter
D/CS	Display/Control System
DOD	Department of Defense
ECS	Environmental Control System
EPS	Electrical Power System
ET	external tank
EVA	extravehicular activity
FA	Flight Analyst

FAIUS	Flight Analyst-interim upper stage
FBCS	fixed base crew station
FC	flight controller
FD	Flight Director
FEP	Front End Processor
FLT	flight
FOD	Flight Operations Director
FP	Flight Planner
FRR	Flight Readiness Review
G&N	Guidance and Navigation
GET	ground elapsed time
GFE	government furnished equipment
GMT	Greenwich mean time
GSFC	Goddard Space Flight Center
ID	Identification
I/O	input/output
IUS	interim upper stage
IVA	intravehicular activity
JSC	Lyndon B. Johnson Space Center
KSC	John F. Kennedy Space Center
LED	light emitting diode
LOA	Landing Operations Area
LPS	Launch Processing System
MBCS	Motion base crew station
MCC	Mission Control Center
MCCSS	Mission Control Center Simulation System
MCE	Mission Control Element
MET	mission elapsed time
MOD	Mission Operations Directorate

MSC	Manned Spacecraft Center
MSFN	Manned Space Flight Network
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
O&P	Operations and Procedures
OAS	Orbiter Aeroflight Simulator
OFT	Orbital Flight Test
ORD	Orbital Requirements Document
PBI	pushbutton indicator
PDR	Preliminary Design Review
RF	radio frequency
RTS	Remote Tracking Station
SAIL	Shuttle Avionics Integration Laboratory
SAMSO	Space and Missile Systems Organization
SCF	Satellite Control Facility
SDL	Software Development Laboratory
SESL	Space Environment Simulation Laboratory
SMCC	Shuttle Mission Control Center
SMS	Shuttle Mission Simulator
SOW	Statement of Work
SPS	Shuttle Procedures Simulator
SRB	solid rocket booster
SSV	Space Shuttle Vehicle
STA	Shuttle Training Aircraft
STC	Satellite Test Center
STDN	Space Tracking and Data Network
STS	Space Transportation System
STSMD	STS Mission Director
TAEM	Terminal Area Energy Management

TBD	to be determined
TDRS	Telemetry Data Relay Satellite
TOR	Technical Operating Report
TV	television
VAFB	Vanderberg Air Force Base
VAIUS	Vehicle Analyst-interim upper stage
VAO	Vehicle Analyst-Orbiter
VFT	Vertical Flight Test
WIF	Water Immersion Facility

PART 2

ORBITAL REQUIREMENTS DOCUMENT

ANNEX 1 (SAMPLE)

INTERIM UPPER STAGE

FOR SPACE TRANSPORTATION SYSTEM

SECTION 1
ADMINISTRATIVE

1.1 ORBITAL REQUIREMENTS APPROVAL PAGE

ORBITAL REQUIREMENTS DOCUMENT

ANNEX 1

INTERIM UPPER STAGE
FOR SPACE TRANSPORTATION SYSTEM PROGRAM

1.2 PREFACE

This document constitutes an annex to the STS Orbital Requirements Document (ORD) and covers those requirements pertaining to the interim upper stage (IUS). The document defines the support required of the Satellite Control Facility (SCF) and furnishes the SCF with a basis for planning, implementing and changing hardware and software facilities and/or manpower needed to support the STS.

The format and information content of this ORD Annex are as specified in SAMSO Exhibit 61-98, Revision B.

1.3 UPDATING INSTRUCTIONS

Revisions to this document will be issued by the USAF SAMSO (LV-RO) as required to reflect changes in support requirements as they occur. It is not intended to revise the document on a scheduled basis.

When revisions are required, each published revision will contain the following:

- Title page with approval signature
- Updated instructions page
- Revised summary page
- Revised table of contents
- Revised pages

Page numbers are in consecutive order within each subsection, e.g., 2.1.1, 2.1.2, 2.1.3. Additional pages required due to a revision will be numbered to follow the previous page by the addition of consecutive decimal digits, e.g., 2.1.1, 2.1.1.1, 2.1.1.2. Each revised page will have the revision number and date of issue.

1.4 REVISION SUMMARY

Description

Original Issue

Date

October 1974

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1.6 SECURITY GUIDE AND DOD PRIORITY

Information on this page TBP by DOD.

1.7 DISTRIBUTION LIST

The Distribution List for this document TBP by DOD.

1.8 KEY PERSONNEL

The list of key personnel TBP by DOD.

1.9 DEFINITIONS OF SPECIAL TERMS

TBP

1.10 DEFINITION OF ABBREVIATIONS

CCU	Central controller unit
CCLS	Computer controlled launch set
CEM	Co-elliptic maneuver
D/A	digital-to-analog
DCU	Digital computer unit
FTFD	Field test flight director
GSE	Ground support equipment
IMG	Inertial measurements group
IUS	Interim upper stage
IRU	Inertial reference unit
KSC	John F. Kennedy Space Center
LPS	Launch Processing System
ORD	Orbital Requirements Document
PCM	Pulse code modulated
PRN	Psuedo random noise
PU	Propellent utilization
RC	Resistance-capacitor
RCS	Reaction control system
RF	Radio frequency
RMU	Remote multiplexer unit
SCF	Satellite Control Facility
SCU	Sequence control unit
SEC	System electronics unit
SGLS	Space Ground Link Subsystem
SIU	Servo inverter unit
SMCC	Shuttle Mission Control Center
SPO	System program office

STC	Satellite Test Center
TPF	Terminal phase final
TPI	Terminal phase initiation
TT&C	Tracking, Telemetry and Command
VAFB	Vandenberg Air Force Base
VCO	Voltage controlled oscillator

SECTION 2

GENERAL SYSTEMS INFORMATION

2.1 PROGRAM

2.1.1 Program Description. The STS is a new USAF program which will employ the Earth Orbiting Space Shuttle, a manned, winged, reusable spacecraft, as well as several configurations of upper stage vehicles, for the overall purposes of deploying, servicing, retrieving, and returning to earth with DOD satellites. This document addresses the on-orbit requirements in support of interim upper stage vehicles to be utilized by the DOD during initial phase of the STS program; a separate ORD has been prepared for the Earth Orbiting Shuttle.

The upper stage vehicles to be utilized by DOD may be divided into two broad categories, as follows:

- A. Early flights of the Shuttle will utilize an *interim upper stage* (IUS) for the sole purpose of transporting and deploying one or more satellites from a low earth orbit (100-400 nmi altitude) to a higher altitude not attainable by the Shuttle. Many DOD missions are concerned with the placement of satellites in synchronous and/or near-synchronous orbits (altitude approximately 19400 nmi). At the release date of this ORD the IUS vehicles have not been definitized.
- B. Later flights of the Shuttle will utilize a more sophisticated upper stage, designated as the Tug. The Tug will differ from the IUS in two important ways, namely:
 - 1. The Tug is substantially larger than any IUS vehicle mentioned above; consequently, the Tug can transport heavier satellites, or it can return with certain DOD satellites from synchronous altitude to a low earth orbit, such as to permit retrieval of the mated pair by the Shuttle.
 - 2. The Tug will possess the capability to rendezvous with, and dock with, satellites in orbits above those achievable by the Shuttle, followed by return to the low

Shuttle orbit. By contrast, the IUS vehicles will not possess the rendezvous/docking capability.

DOD flights will originate either at KSC or at Vandenberg Air Force Base (VAFB). Only those originating at KSC will utilize the IUS; later flights from VAFB may employ the Tug, but requirements for such flights are not yet defined.

When the vehicle for use as an IUS is determined, it may be provided systems that would permit its recovery for reuse. For purposes of this document, such an IUS is considered to be a *recoverable* IUS. The IUS may not have this capability; even with this capability, the IUS may not, on certain missions involving heavy satellites and/or a high deployment altitude, possess the energy capability to return to the Orbiter following satellite deployment. In either of these cases, for the purpose of this document, such an IUS is considered to be an *expendable* IUS.

In the event of certain anomalous behavior of the IUS and/or its mated satellite load, it may be both possible and desirable for the IUS to return to a Shuttle-retrieval position rather than deploying the satellite(s); in this case an IUS planned to be expendable may suddenly become reuseable. Also, in this case ground support will become both time and technically critical. However, it is emphasized that the IUS cannot rendezvous and dock with a satellite; if the IUS is to return a failed satellite to the Shuttle rather than executing a deployment, appropriate commands must be transmitted from the ground before the deployment is scheduled to occur and while the IUS still possesses sufficient propellents.

During a normal flight an expendable IUS will be preprogrammed to perform its intended functions. In these flights support from the ground will be limited to tracking and monitoring, and support from the Shuttle will be limited to possible final state vector update and initiation of the IUS sequences.

When a reuseable IUS is in flight, most IUS functions will be preprogrammed into the vehicle, but additional update data may be required by the IUS, from the ground, for the return to the Shuttle.

2.1.2 Mission Support. The AFSCF will be required to support IUS orbital operations during liftoff, ascent, and all on-orbit phases of those DOD-STs flights utilizing an IUS. Details of the AFSCF support requirements are provided in Section 4 of this annex. The overall control support of each IUS is dictated by the following top-level mission requirements:

- A. Obtain tracking data for ephemeris determination.
- B. Provide command generation.
- C. Transmit commands on a secure uplink, as required on an operational basis.
- D. Receive telemetry data on a secure downlink; display and distribute data.
- E. Provide for distribution, storage and retrieval of vehicle history data, which serves as the basis for remedial action in the event of anomalous behavior.

2.2 ORGANIZATIONAL STRUCTURE

To be provided by DOD.

2.3 LAUNCH SCHEDULES

IUS launch schedules are contained in Table 2.3-1.

TABLE 2.3-1

SPACE SHUTTLE OPERATIONS PHASE LAUNCH TRAFFIC

CALENDAR YEAR	KSC							VAFB		TOTAL
	DOD(1)		NASA(2)					NASA		
	UPPER STAGE		UPPER STAGE	SHUTTLE				TUG	SHUTTLE	
	IUS	TUG	IUS	TUG						
80	3	0	0	0	14	0	0	0	17	
81	5	0	12	0	20	0	0	0	37	
82	5	0	5	0	22	0	0	1	33	
83	5	0	13	0	21	8	0	7	54	
84	2	5	0	14	21	9	4	6	61	
85	2	6	0	15	27	9	1	8	68	
86	4	3	0	17	25	9	1	9	68	
87	3	4	0	12	25	9	2	6	61	
88	3	3	0	12	27	9	2	7	63	
89	2	5	0	11	22	9	2	9	60	
90	3	5	0	14	28	9	2	9	70	
91	2	6	0	11	28	9	2	7	65	
TOTAL	39	37	30	106	280	80	16	69	657	

(1) DOD SPACE MISSION MODEL (FY 1980-1991), REV. 3, 16 AUGUST 1973

(2) NASA TRAFFIC FROM NASA TMX-6451, REV. 2, JANUARY 1974

2.4 FUNCTIONAL DESCRIPTION

2.4.1 General. The IUS will be launched while stowed within the cargo bay of the Shuttle; DOD program requirements call for launches with the IUS only from KSC. Launch windows vary from one mission to the next and will be provided as part of the overall mission planning for particular missions. During the 1980-1991 period DOD is scheduled to fly 76 missions from KSC. Early flights will utilize the IUS, and later flights will utilize the Tug as an optional upper stage.

2.4.2 Launch and Ascent. Following launch the Shuttle, with its stowed IUS and attached satellite(s), will be injected into an elliptical parking orbit. Perigee and apogee altitudes and the orbital inclination are mission-peculiar. As a general rule, the Shuttle will orbit at about 100-130 nmi, although certain missions call for an apogee up to about 400 nmi.

2.4.3 Payload Deployment. Following insertion of the Shuttle into its parking orbit, the Shuttle cargo bay doors will open and the IUS, with its attached satellite(s), will be deployed. Separation of this payload combination is designed for a nominal (TBD) fps and tipoff angular rate of less than (TBD) deg/sec. The IUS will then be reoriented so that its roll axis lies along the velocity vector and the IUS altitude control system (ACS) will be activated.

2.4.4 Payload Postdeployment Events. Following deployment of the payload, the Shuttle crew will ensure that the payload orbit is stable. The Shuttle will then move to a safe distance (up to 30 nmi) from the IUS. By radio command from the Shuttle, via a Space Ground Link Subsystem (SGLS) RF link, the IUS sequencer will be initiated. The IUS propulsion system will then fire in order to place the IUS in a transfer orbit.

2.4.5 IUS Transfer and Deployment - Expendable IUS. The IUS engine burns following deployment from the Shuttle are intended to produce a transfer orbit which will attain the required apogee for the satellite(s). The IUS is preprogrammed to perform all guidance and navigation functions for this transfer. At near apogee the orbit plane will be finalized (plane change) and the orbit circularized. For approximately 75 percent of the DOD flights from KSC, the intended satellite orbit is synchronous-equatorial.

Just prior to satellite deployment the IUS will provide an arm and fire signal to separate the satellite. Subsequent to separation the IUS will be reoriented, and fired into a non-interfering orbit until propellant exhaustion.

2.4.6 Post-Satellite Deployment. Full activation procedures for DOD satellites are mission-peculiar; typical events may include:

- A. Uncaging of a despin platform
- B. Release of tracking, telemetry and command (TT&C) antennas
- C. Unfurling of solar panels
- D. Satellite spinup (if and as required)
- E. Activation of communications subsystem (this event will occur immediately following release from the Shuttle in some missions)
- F. Drift to final position
- G. Satellite attitude alignment

Command, checkout, and control of the satellite will be accomplished by the AFSCF.

2.5 INTERIM UPPER STAGE SYSTEMS

2.5.1 Functional Relationship Between Subsystems. Subsystems include:

- Controls
- Propulsion
- Guidance
- Communication
- Navigation
- Electrical Power
- Electrical Distribution
- Structures
- Thermal Control

The system mission is primarily accomplished with support from the subsystems as follows:

- Satellite stabilization, station keeping and antenna pointing - Controls and Propulsion Subsystems.
- Ground control for command of functions or adjustments - Communications and Controls Subsystems.
- Primary Electrical Power - Electrical Power Subsystem.
- Secondary Electrical Power - Electrical Distribution Subsystem.
- Status and performance monitoring - Communications and Electrical Distribution Subsystem.
- Spacecraft guidance - Guidance Subsystem.
- Spacecraft navigation - Navigation Subsystem.

Spacecraft command and control is implemented primarily through onboard stored-program commands of the individual spacecraft

functions. Automatic onboard control logic is also incorporated into the Electrical Distribution Subsystem for:

- Spacecraft turn-on and deployment subsequent to separation.
- Switching of the Communications Subsystem from standby to the operational mode during the command process.

2.5.2 Description of Subsystems. TBD

2.6 MISSION SEQUENCE OF EVENTS

2.6.1 General. This section outlines the IUS mission events for high-altitude deployment missions when the IUS will be recoverable by the Shuttle. Mission events for an expendable IUS are sufficiently similar as to not require elaboration.

2.6.2 Geosynchronous Deployment Mission

2.6.2.1 Mission Description. This mission is representative of the deployment of a payload into a geosynchronous orbit. The Orbiter, IUS, and satellite are launched due east from KSC and ascend into a 50×100 nmi, 28.5 degrees parking orbit. The IUS/satellite separates from the Orbiter and performs the necessary phasing, transfer and plane change maneuvers to place the satellite at the desired longitude location in the synchronous orbit. After satellite deployment, the IUS returns to an orbit 15 nmi above the Orbiter parking orbit. After IUS retrieval, the Orbiter waits in parking orbit (115 nmi) for phasing and return to KSC.

The IUS/satellite payload will be under Orbiter hardwire monitor from liftoff through parking orbit deployment. Predeployment checkout of the IUS and the satellite will consist of a hardwire, minimal functional check. After deployment, initialization and separation, an RF check will be performed by the Orbiter to verify the command and control functions. During rendezvous, the Orbiter will again perform an RF checkout of the IUS and condition it for retrieval.

2.6.2.2 Orbital Timelines. Two orbital timelines are included in this mission description. Figure 2.6-1 is a timeline for the entire flight phase. Figure 2.6-2 shows the IUS timeline for the deployment mission. Major events are identified on both timelines.

2.6.2.3 Mission Sequence. The mission sequence is given in table 2.6-1 and is intended for use with figure 2.6-1. Times indicated are representative. This mission sequence includes representative orbit parameters.

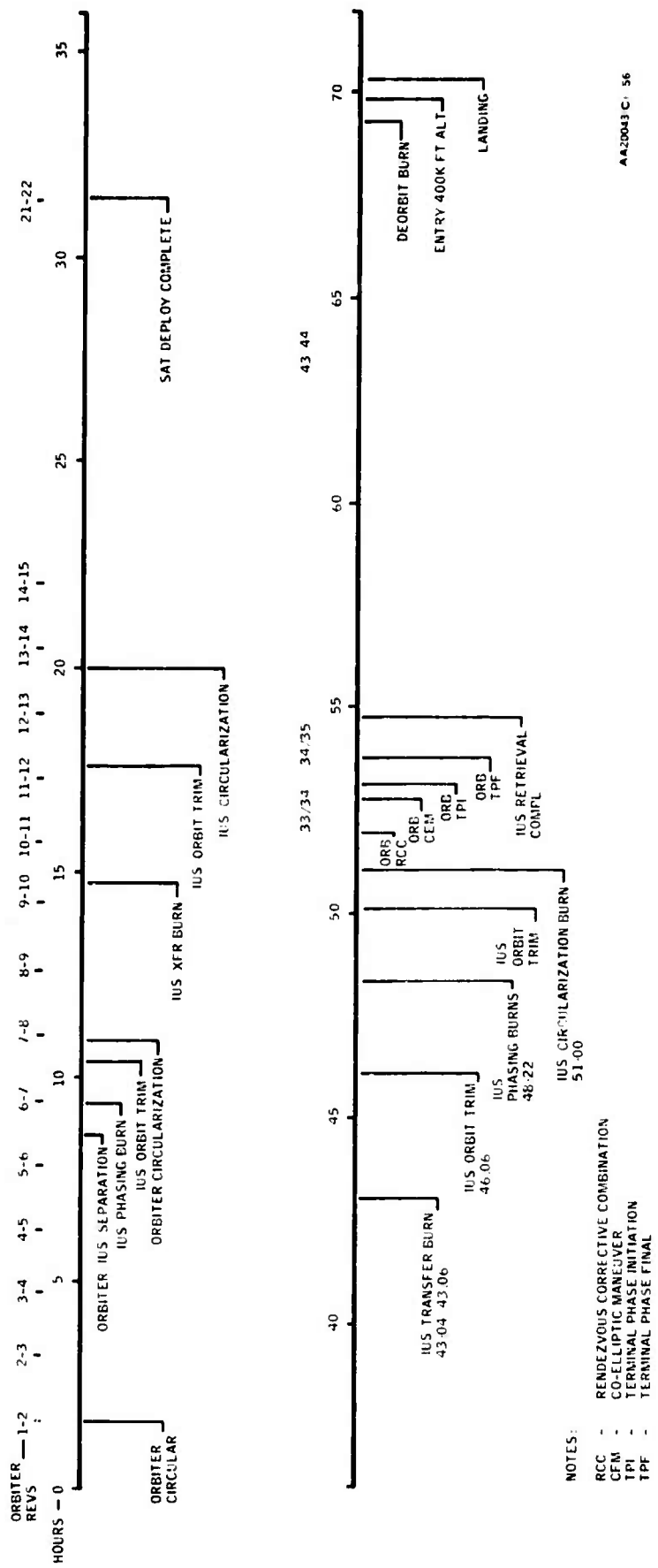
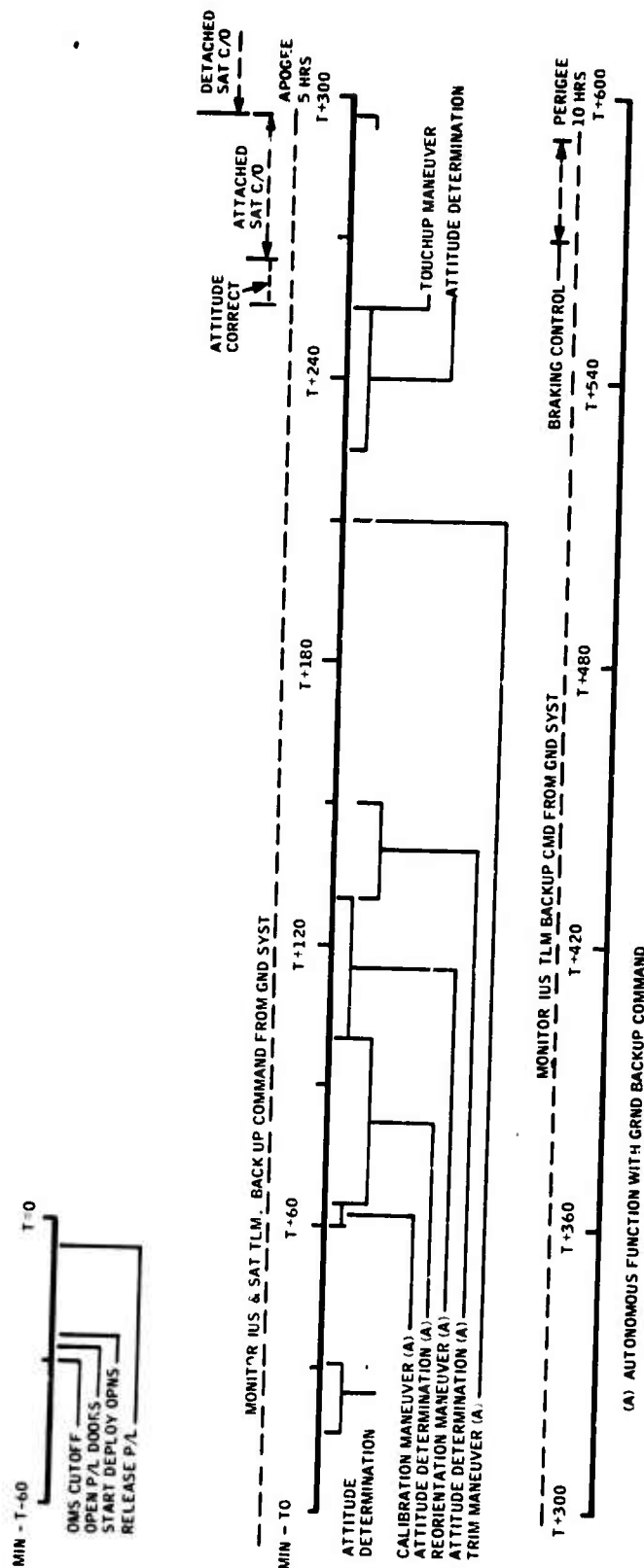


Figure 2.6-1 Orbital Activities for Geosynchronous Mission



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Figure 2.6-2 IUS Deployment of Satellite

2.6.2.4 Flight Operations. Because of its complexity this mission has, for presentation purposes, been separated into four on-orbit segments. The segments are as follows:

- IUS outbound transfer orbit phase
- IUS return transfer orbit phase
- Orbiter/IUS rendezvous
- Retrieval by the Shuttle

Each segment is graphically described in figures 2.6-3 through 2.6-6. For the most part, the figures are self explanatory. The following paragraphs briefly address each segment in more detail.

2.6.2.5 IUS Outbound Transfer Orbit. As shown in figure 2.6-3, checkout of the IUS/satellite combination begins at approximately 1:36:00 ground elapsed time (GET) and is complete by 08:36:15 GET. At completion of the deployment, the IUS outbound transfer orbit phase begins (figure 2.6-3).

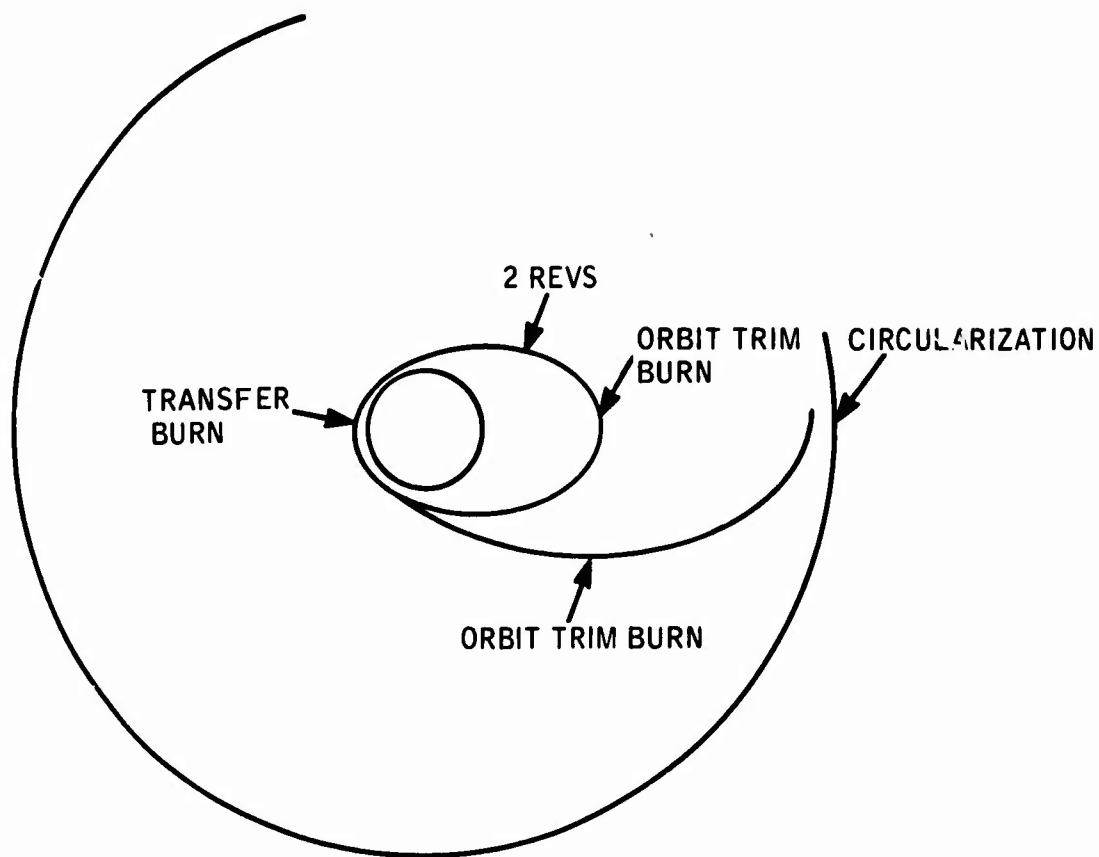
Depending upon the placement location for the satellite, the IUS can begin a direct transfer from the Orbiter parking orbit or can execute one or more phasing orbit revolutions to place the IUS in a more favorable transfer burn position (the more complex phasing orbit maneuver sequence is used to illustrate the transfer burn sequence). In the orbit shown (figure 2.6-3) it is essential that the IUS place the satellite at a specific location in geosynchronous equatorial orbit, requiring plane changes from the 28.5 degree inclination of the parking orbit and two phasing orbit revolutions to place the IUS in the required position for the transfer orbit. As shown on the mission sequence, table 2.6-1, it is mandatory for the IUS to execute the phasing orbit burn at the seventh descending node. The burn is executed at 09:18:05 GET and places the IUS in a 133×3611 nmi/27.9 degrees elliptical orbit. Two revolutions in this orbit place the IUS in the proper position for the transfer burn, such that the IUS arrives at synchronous orbit at the desired location and inclination. Provision is made for an orbit trim during the phasing orbit to adjust the IUS attitude for the transfer orbit burn from 26.0 degree inclination.

TABLE 2.6-1
MISSION SEQUENCE

MISSION	EVENT	TIME (GET)
1	LIFTOFF - ORBITER TARGETED FOR 50/100 nmi/ 28.5°	00:00:00
2	SRB STAGING	00:01:53
3	MECO	00:08:19
4	PARK ORBIT INSERT - 50.21/103.5 nmi/28.5°	00:08:19
5	APOGEE ADJUST - 98/104 nmi/28.49°	00:51:01
6	CIRCULARIZATION - 134/134 nmi/28.49°	01:36:17
7	IUS CHECKOUT - (C/O COMP HALF ORBIT PRIOR TO 7TH DESCENDING NODE. TARGETED TO SYNC ORBITER POSITION)	01:36:17
8	IUS DEPLOY	07:36:15
9	ORBITER SEPARATE - 131/148 nmi	08:36:15
10	IUS PHASING BURN - 7TH DESCENDING NODE 133/3611 nmi	09:18:05
11	ORBITER CIRCULARIZE - 138/138 (BEGIN 33 REVOLUTIONS	10:50:48
12	IUS PHASING REVOLUTIONS (2)	
13	IUS TRANSFER BURN - 133/19,394 nmi/25.0°	14:41:57
14	IUS ORBIT TRIM	≈ 17:35:00
15	IUS CIRCULARIZATION - 19,300/19,296 nmi	19:57:26
16	IUS ORBIT ADJUST (SYNC ORBIT)	AS REQ'D
17	IUS SATELLITE DEPLOY	≈ 31:09:00
18	IUS TRANSFER BURN - 164/19,323 (SYNC) 2 .12°	43:04:05
19	IUS ORBIT TRIM	≈ 46:06:00
20	IUS PHASING BURN - 164/3439 nmi/27.24°	48:21:23
21	IUS ORBIT TRIM	≈ 50:00:00
22	IUS CIRCULARIZATION - 165/161 nmi/28.52°	51:00:08
23	ORBITER RCC BURN - 128/162 nmi/25.51°	51:55:07
24	ORBITER EEM BURN - 162/128 nmi/28.50°	52:43:06
25	ORBITER TPI BURN - 145/169 nmi/28.51°	53:06:58
26	ORBITER TPF - 154/168 nmi/28.49°	53:42:58
27	IUS RETRIEVAL (START)	≈ 53:42:00

TABLE 2.6-1 (CONT'D)

MISSION	EVENT	TIME (GET)
28	EIGHT REVOLUTIONS	
29	DEORBIT BURN - 10/161 nmi/28.48°	69:25:06
30	LANDING	70:26:01



IUS EVENTS PHASING BURN THROUGH OUTBOUND CIRCULARIZATION

11	PHASING BURN	09:18:05	133/3611 NMI	27.19°
12	ORBIT TRIM			
13	TRANSFER BURN	14:41:57	133/19300	26.0°
14	ORBIT TRIM			
15	CIRCULARIZE	19:57:26	19300/19297	0.0°

ORBITER NOT SHOWN
 CONTINUES IN PARK ORBIT UNTIL IUS RETURN (33 REVS)
 138/138 NM 28.52°

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Figure 2.6-3 IUS Outbound Transfer Orbit Phase

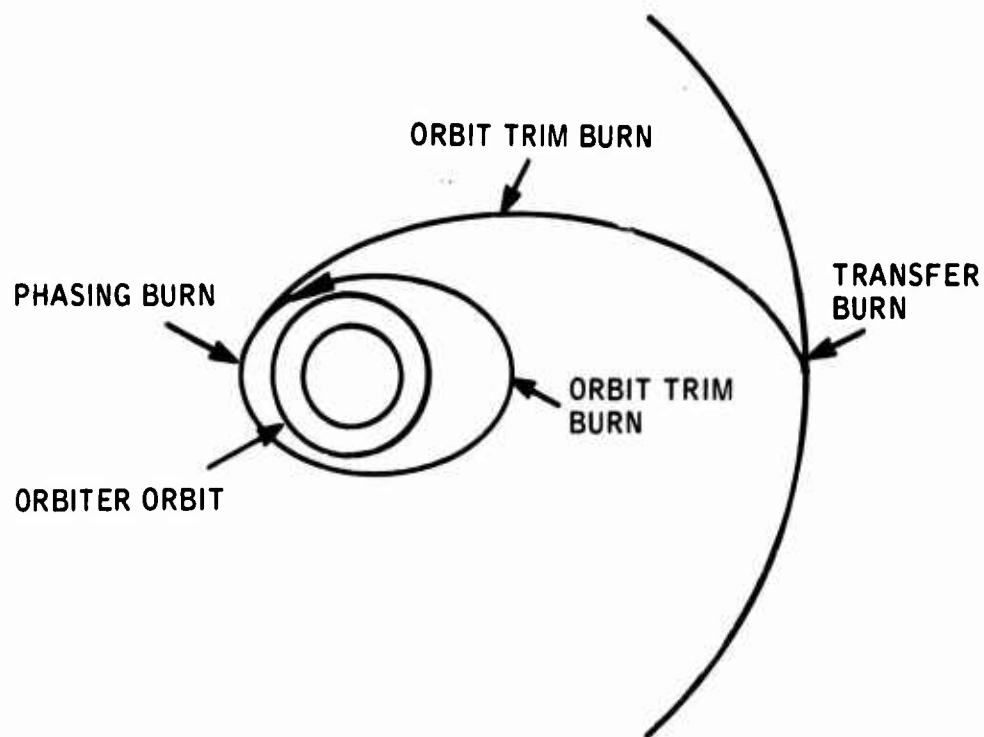
At 14:41:57 GET the IUS executes the transfer burn at the perigee of the phasing orbit (133.0 nmi/26.0°). An orbit trim is executed during the transfer orbit ascent to adjust IUS attitude for the circularization burn and plane change. Transfer orbit plane and circular orbit plane coincide at 19,400 nmi and the IUS executes a circularization/plane change burn into a 19,400 × 19,400 nmi/0.0 degree orbit. Any necessary orbit adjustment is accomplished by the IUS and the satellite is deployed. Initiation may be by the IUS separation function or by ground command. Complete operational checkout of the satellite is the responsibility of the AFSCF ground system. Moreover, a predeployment check may be made to determine basic command and control capability, such that if the checkout is negative, the satellite can be returned by and with the IUS. The complete operational check, including sensor stimulus/response, can be made only after separation and initialization.

2.6.2.6 IUS Inbound Transfer Orbit. As stated previously, this representative mission has been made complex for illustrative purposes and severe time constraints have been placed on orbit maneuvers to indicate requirements; in this case, the IUS phasing orbits to adjust to specific deployment requirements.

If it were not for the time constraint imposed by the IUS de-orbit time, a simple direct transfer orbit to the Orbiter parking orbit could be made at any time. Assuming, however, that total on-orbit time should be minimized, the IUS phasing orbit has been selected so that the IUS can be placed within 90 nmi of the Orbiter -- thus minimizing rendezvous and retrieval time. The inbound transfer orbit is illustrated in figure 2.6-4.

At 43:04:05 GET, the IUS executes a de-orbit transfer burn into a 164 × 19,323 nmi/26.12 degree elliptical orbit. The inbound descent requires approximately 5 hours, during which an orbit trim maneuver may be required to adjust the IUS attitude for the phasing burn. At 48:21:23 GET, the phasing orbit burn is executed at the transfer orbit perigee (164 nmi), placing the IUS in a 164 × 3439 nmi/27.24 degree phasing orbit. After one orbit, the IUS executes a circularization burn at the perigee of the phasing orbit, resulting in a 165 × 165 nmi/28.52 degree circular orbit, above the Orbiter parking orbit.

As shown in the mission sequence, table 2.6-1, the Orbiter is completing the thirty-third revolution in a 134 × 134 nmi/28.5 degree orbit and is within tracking sensor range of the IUS (behind and below).



IUS EVENTS POST-DEPLOY (RETRIEVAL)

18	TRANSFER BURN	43:04:05	164/19323	26.12
19	ORBIT TRIM			
20	PHASING BURN	48:21:23	164/3439	27.24
21	ORBIT TRIM			
22	CIRCULARIZATION	51:00:08	161/165	28.52

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Figure 2.6-4 IUS Return Transfer Orbit Phase

IUS circularization into the rendezvous orbit completes the IUS inbound transfer orbit phase.

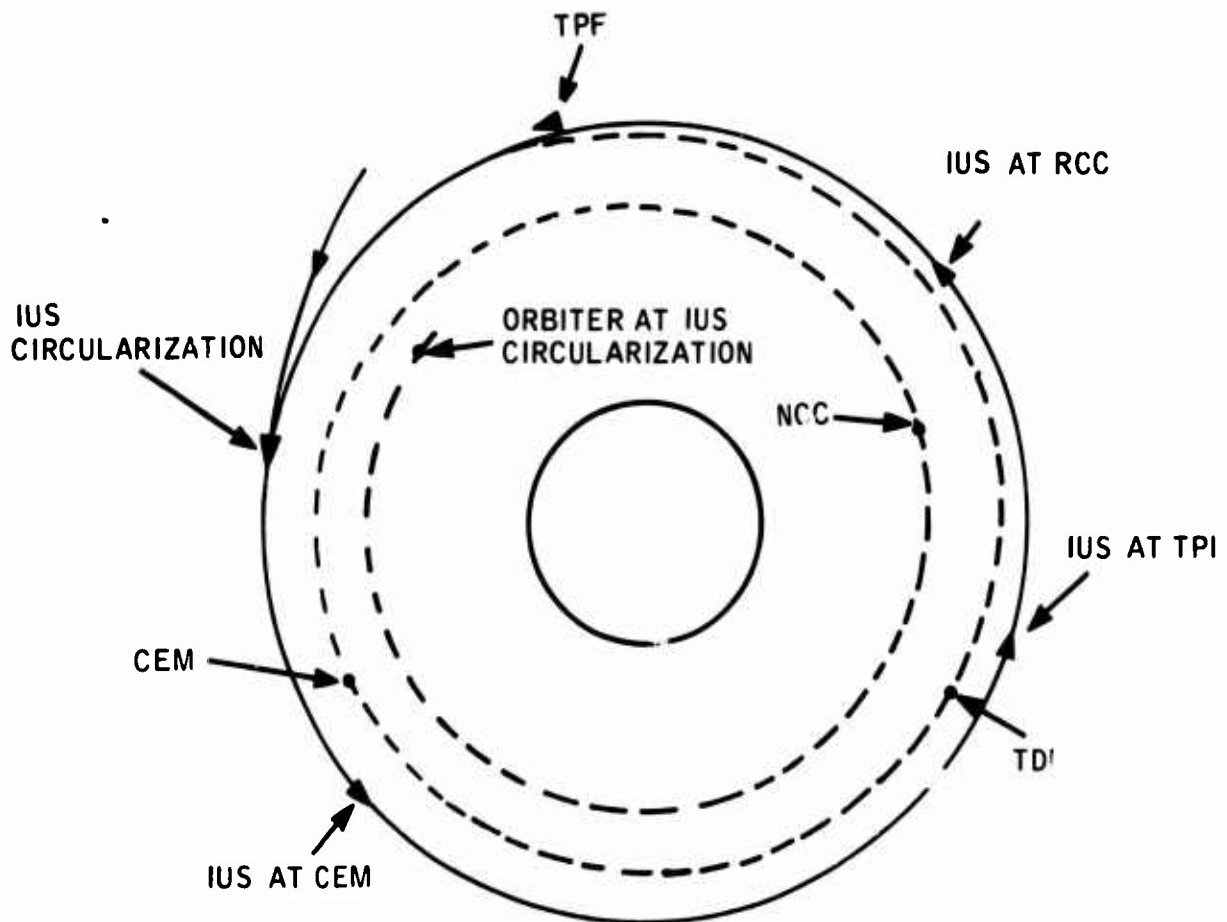
2.6.2.7 IUS/Orbiter Rendezvous. The Orbiter is capable of at least two types of rendezvous sequences: direct ascent and multi-revolution, co-elliptic. Direct ascent rendezvous must be controlled onboard the Orbiter because network support is not available on a continuous basis. Figure 2.6-5 illustrates the rendezvous sequence.

Trajectory calculation for the co-elliptic sequence must be accomplished both onboard the Orbiter and by the AFSCF ground system. The Orbiter crew must be able to analyze the effect of any correction burn on the altitude, phasing, and time of rendezvous, while the ground system processes the same information to determine station contact parameters. The Orbiter assumes prime responsibility as soon as its sensors acquire the target.

It is illustrated in figure 2.6-5 that the IUS returns to an orbit co-elliptical to the Orbiter parking orbit somewhat higher than the parking orbit altitude. The specific orbits, shown on the mission sequence, table 2.6-1, are 134×134 nmi for the Orbiter circular parking orbit and 165×161 nmi for the IUS co-elliptic orbit.

Rendezvous between the Orbiter and the returning IUS begins following the IUS circularization burn. As stated, IUS circularization is at the perigee of the inbound transfer orbit or (as in this case) the phasing orbit. The phasing orbit places the rendezvous target within minimum maneuver range of the Orbiter. The Orbiter immediately begins rendezvous sensor acquisition. Fifty-four minutes later, the Orbiter initiates a sequence of maneuvers resulting in rendezvous 2.7 hours after the IUS circularization burn. The Orbiter executes a rendezvous corrective combination (RCC) burn and a co-elliptic maneuver (CEM) burn to bring it in place for the terminal phase initiation (TPI) and terminal phase final (TPF). Due to their small magnitude, the TPI and TPF maneuvers are performed using only the reaction control system (RCS).

The RCC burn is intended to place the IUS orbit 10 nmi above that of the Orbiter and to establish a proper phase angle (about -1.1 degree) at the CEM point. Residual out-of-plane error would be corrected by this maneuver. The CEM maneuver circularizes the orbit and nulls the residual out-of-plane velocity between the two vehicles. Except for attitude control, the IUS becomes passive-cooperative for the final phase of the mission; the Orbiter becomes



IUS /ORBITER EVENTS - CIRCULARIZATION THROUGH TPF

22	IUS CIRCULARIZATION	51:00:08	161/165	28.52°
23	ORBITER RCC	51:55:07	128/162	28.51°
24	ORBITER CEM	52:43:06	149/155	23.50°
25	ORBITER TPI	53:06:58	145/169	28.51°
26	ORBITER TPF	53:42:58	154/168	28.49°

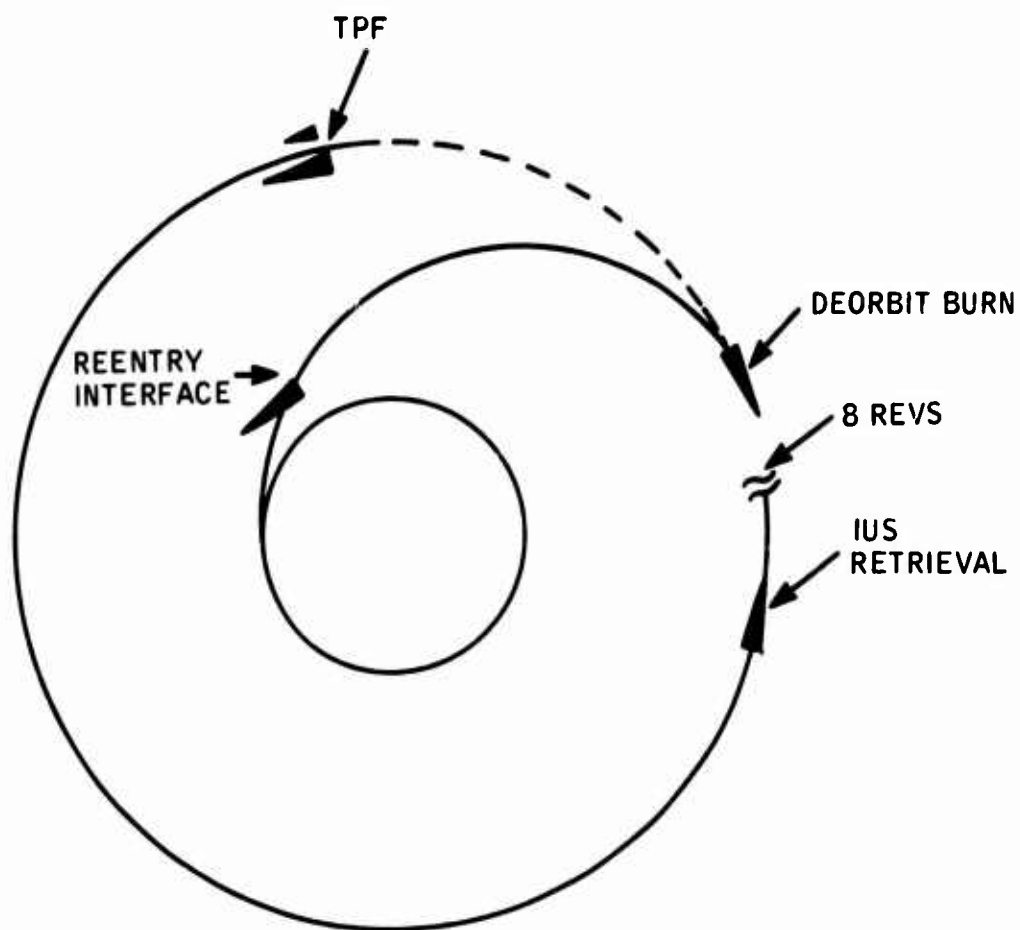
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Figure 2.6-5 IUS/Orbiter Rendezvous

the active vehicle. After the CEM, the phase angle between the Orbiter and the IUS is about 1.1 degrees and the Orbiter reduces this range from the IUS at a near-constant rate. Approximately 45 minutes later, the Orbiter reaches the TPI point, and the final approach phase of the rendezvous is initiated (53:06:58 GET) on the mission sequence.

2.6.2.8 Retrieval of the IUS. Retrieval operations (illustrated in figure 2.6-6) begin at approximately 53:43:00 GET and consist of the jettison of any remaining IUS fuel, safing functions, sufficient commands to correct the IUS attitude for retrieval, and deactivation of the IUS reaction control system (attitude control).

Grapple, retract, and securing of the IUS in the payload bay require no more than 20 minutes and include remating of the IUS umbilicals in the payload bay, primarily for safety purposes. The spacecraft then prepares for reentry and landing at KSC.



IUS /ORBITER EVENTS - RETRIEVAL , DEORBIT , & LANDING

26	TPF	53:42:58	154/168	28.49 ⁰
27	RETRIEVAL	45:02:58		
29	DEORBIT	69:25:06	10/161	28.48 ⁰
30	LANDING	70:26:01		

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Figure 2.6-6 Retrieval Phase (Also Illustrates Landing)

2.7 GROUND SUPPORT FUNCTIONS

The AFSCF will conduct the orbital operations required to support each IUS deployment mission. The operations support will include:

- Vehicle tracking of the mated IUS/satellite preceding satellite release.
- Vehicle tracking of the separated vehicles
- Telemetry data receiving, recording, processing, and distribution
- IUS command generation, transmission, and verification
- Satellite commanding, control, and housekeeping

This support will be provided by remote tracking stations, as visibility to the vehicles permits, dependent upon mission requirements, elapsed time, and station location. Specific support requirements are mission peculiar.

Station scheduling and configuration direction in support of IUS flights will be provided by the Satellite Test Center (STC).

Support requirements include the use of the station SGLS pseudo-random noise (PRN) signals for range and carrier doppler shift (range - rate), and the *optional* use of the COMSEC ground equipment for encryption of transmitted commands and decryption of received telemetry. The STC will support maneuver command operations using ephemeris data supplied by a (TBD) orbit ephemeris system and telemetry inputs supplied from the IUS and from the deployed satellite(s).

2.8 SCF SUPPORT WORKLOAD

Tracking support of the mated IUS/satellite(s) will be required during the orbital transfer to high altitude to correct possible IUS injection errors and to provide the satellite position accuracy required to station the satellite(s) at the intended location(s). Tracking support is also required for the deployed satellite(s) and for the return-to-Shuttle phase for a reuseable IUS.

Telemetry support will be required during these periods to determine the status of vehicle subsystems and to determine if attitude correction maneuvers, or any other remedial action, are required.

Tracking and telemetry support requirements will be mission-peculiar and will include those tracking stations which have a clear line of sight to the IUS and satellite(s) on a scheduled basis. It is estimated that minimum support requirements will be as follows:

- A. Support for up to (TBD) minutes as soon after deployment from the Shuttle as a line-of-sight permits.
- B. Support for at least (TBD) minutes approximately halfway through the orbital transfer coast.
- C. Support commencing approximately (TBD) minutes prior to deployment of any satellite from the IUS, and continuing through deployment, satellite checkout, commencement of satellite operations, and either the initiation of the (reuseable) IUS return orbital transfer or the depletion burn of an expendable IUS.
- D. Support of a reuseable IUS for a minimum of (TBD) minutes approximately halfway through the orbital transfer coast of a reuseable IUS.
- E. Support contact for up to (TBD) minutes with the Shuttle, following retrieval of a recoverable IUS, as line-of-sight permits.

SECTION 3

IUS FLIGHT ELEMENT CHARACTERISTICS

3.1 IUS VEHICLE PARAMETERS

TBD

3.2 IUS TRAJECTORIES

Each mission utilizing the IUS dictates a unique set of trajectory parameters which are defined in the mission annexes. The IUS progresses through a series of mission dependent flight phases. The flight phases include the following:

- Ascent to satellite ejection orbit
- Insertion into satellite ejection orbit
- Satellite ejection orbit
- Satellite ejection
- Descent to IUS/Orbiter rendezvous orbit
- Rendezvous orbit

Each flight has an attendant set of trajectory parameters. The trajectory parameters (depending upon flight phase) include the following:

- Altitude or apogee radius, perigee radius and arguments thereto
- Period
- Longitude
- Latitude
- Ascending node
- Descending node
- Inclination angle

Figures 2.6-3 through 2.6-6 of this annex depict the on-orbit phases of a representative recoverable IUS flight profile, beginning with deployment from the Orbiter and terminating with insertion into rendezvous orbit.

3.3 TRACKING

3.3.1 Tracking Aids

3.3.1.1 Orbital Transfer Phase. Prior to separation of the satellite(s) from the IUS, the satellite systems capable of providing tracking assistance are inactive. During this period, angles-only tracking information can be obtained by the SCF remote tracking stations utilizing the IUS S-band telemetry RF signal. The RF carrier frequencies (i.e., SGLS channel selection) for the IUS and its mated satellite(s) are mission peculiar and will be selected prior to individual missions. Any of the 20 standard SGLS channels may be used for the IUS; a separate channel(s) will be used for communications to the satellite(s). During the orbital transfer, tracking will occur only between the IUS and one or more SCF ground stations.

3.3.1.2 Orbital Phase. Following separation of the IUS and its mated payload from the Orbiter, the SCF remote tracking stations will be able to measure the following parameters via the SGLS telemetry system:

- Range through time shift of the PRN range code
- Range-rate through coherent carrier doppler shift
- Azimuth and elevation angle based on the apparent angle of arrival of the RF signal transmitted from the IUS.

3.3.2 Active Tracking System

3.3.2.1 PRN Ranging. Range is determined by measuring the time shift (propagation delay) experienced by a pseudo-random binary ranging code which is specifically chosen because of its correlation characteristics. This code, generated in the transmitter coder, phase-modulates the ground-to-satellite carrier, as shown in figure 3.3-1.

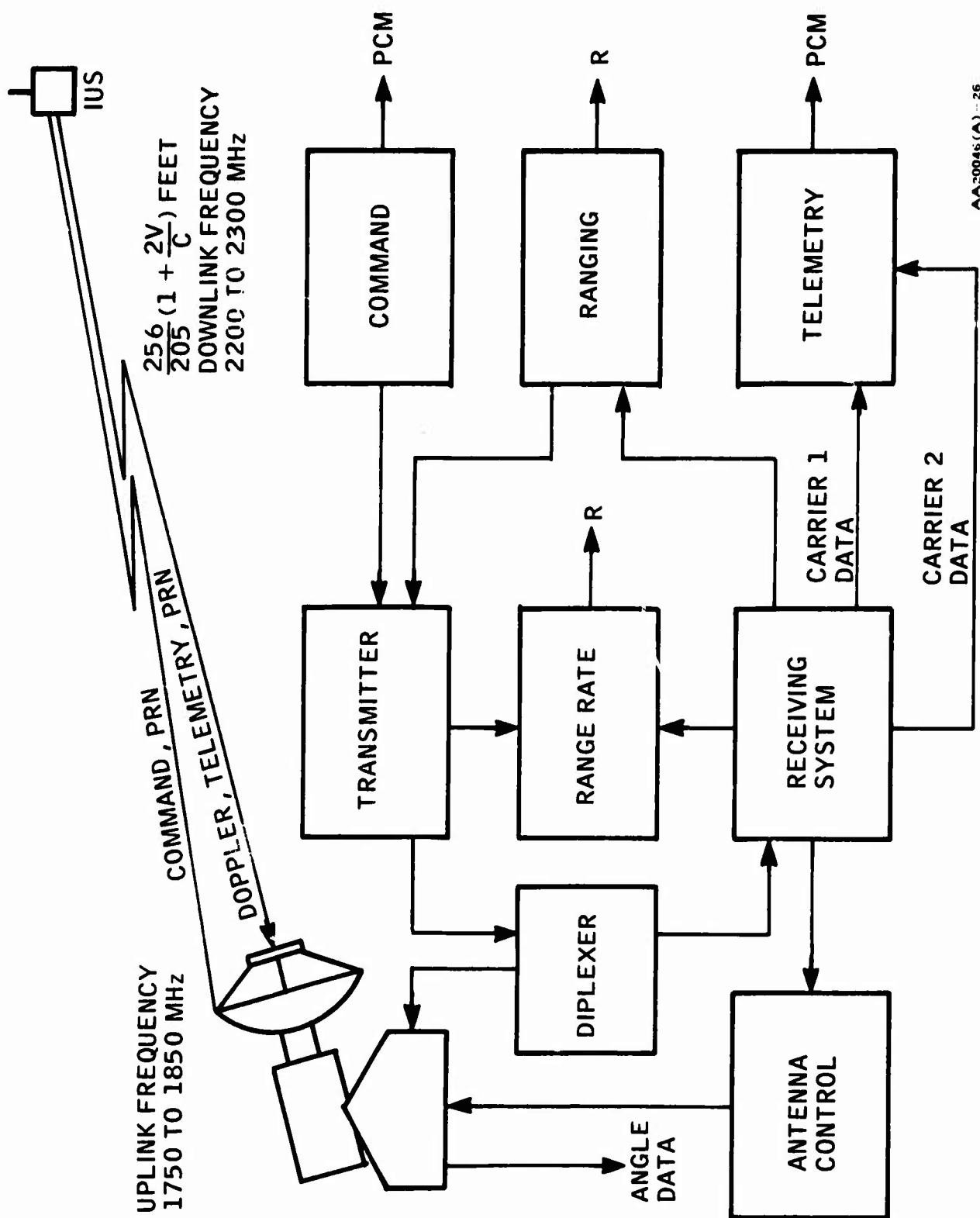
3.3.2.2 Doppler Frequency Shift Tracking. Both one-way and two-way techniques can be implemented for this range rate tracking function. In the two-way technique, a precise determination of

range-rate is made possible through the use of the satellite phase-locked transponder which generates a coherent carrier at a rational fraction ($256/205$) of the received frequency. The satellite transponder is interrogated by the ground transmitter operating at a frequency of $205/256$ times the base frequency ($f_r \times$). This results in a received signal at the satellite of $205/256 (f_r \times)$ plus one-way doppler shift. This frequency is multiplied by $256/205$ in the satellite transponder and retransmitted to the ground where it is received with additional one-way doppler, as shown in figure 3.3-2. Precise range-rate data is extracted through appropriate mixing of the filtered received signal from the ground receiver with signals from the ground transmitter. Phase-lock techniques are also utilized in the ground receiver to provide an efficient tracking filter for the received carrier. This technique permits near optimal demodulation of the telemetry and ranging information carried by this signal.

In the absence of an uplink signal, one-way doppler tracking is possible by using a stable crystal oscillator in place of the voltage-controlled oscillator (VCO) to drive the satellite transponder transmitter. This is termed the "noncoherent" operating mode for the transponder.

The signal is subsequently demodulated in the satellite command receiver, filtered, and used to remodulate the satellite-to-ground carrier without further processing. This carrier is processed by the ground receiving equipment to provide a noise-corrupted, delayed replica of the original transmitted signal. A local model of the ranging code is generated in the receiver coder and, by a generated delay, is made to coincide with the received code through the use of cross-correlation techniques. The measured delay with respect to the transmitted code is equal to the round trip transit time and thus measures satellite range. Once range acquisition has been accomplished, the data may be continually updated using internal doppler signals.

To assure an unambiguous measurement of the satellite range, the code period must be greater than the round trip propagation time. Two code lengths will be provided for the SGLS; this permits an unambiguous range determination to 400,000 nmi for the long code and 5000 nmi for the short code. The ranging codes are formed by a synchronous combination of four binary code components plus a two-bit clock code. To further reduce the time required for acquisition, a short code is provided for range uncertainties of less than 5000 nmi.



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Figure 3.3-2 Doppler Shift System Block Diagram

3.3.3 Antenna Gain and Isotropic Antenna Patterns. The IUS will employ right-hand circularly polarized antenna subsystem for reception of uplink commands, ranging, and transmission of downlink telemetry. It is a DOD requirement that communications to the IUS, from a remote tracking station, shall be possible independent of the IUS attitude. The onboard antenna subsystem configuration to meet this requirement has not yet been defined; correspondingly, the antenna subsystem gain and radiation pattern is TBD. Operation shall be possible on any of the 20 standard SGLS channels.

3.4 TELEMETRY DOWNLINKS

There are two downlinks in the IUS for medium and high-rate telemetry. The medium rate telemetry downlink carrier is phase coherent with the uplink carrier and contains a range signal, IUS health and status data and command authentication of verification information. The high rate telemetry downlink contains satellite data.

3.4.1 RF Configuration

<u>Characteristic</u>	<u>Requirement</u>
Frequency range	2200-2300 MHz (20 standard SGLC carrier frequencies)
Frequency assignment	TBD (mission peculiar)
Transmitter power output	TDB (1.0 watt typical)
Transmission loss from transmitter to antenna	TBD

3.4.2 Modulation Technique

<u>Characteristic</u>	<u>Requirement</u>
<u>Medium rate TLM</u>	
Subcarrier Frequencies	1.024 MHz and 1.7 MHz
Subcarrier Modulation	
1.024 MHz	PCM/PSK
1.7 MHz	PCM/FM/FM
Subcarrier Frequency Tolerance	
1.024 MHz	±60 Hz
1.7 MHz	±180K Hz
Subcarrier Frequency Stability	TBD
Telemetry PCM Bit Rate	
1.024 MHz	7.8 b/s to 128 kb/s
1.7 MHz	125 b/s to 256 kb/s

<u>Characteristic</u>	<u>Requirement</u>
Telemetry bit stability	TBD
Telemetry word length	TBD
Telemetry frame length	TBD
PRN modulation technique on to carrier	PM

High rate TLM

Subcarrier Frequency	5 MHz below medium rate TLM carrier frequency
Subcarrier frequency stability	TBD
Subcarrier modulation technique	PCM/PSK/PM
Telemetry data rate	128 kb/s to 1024 kb/s
Telemetry bit stability	TBD
Telemetry word/frame length	TBD

3.4.3 Word/Frame Structure. Digital and discrete input signals are processed into a PCM time-multiplexed serial bit stream, encrypted, and sent to transmitter equipment.

The mainframe and subframe word structure are TBD.

3.4.4 Encryption Equipment. The IUS may contain GFE TBD telemetry encryptors to accept the PCM coded telemetry data and route the secured output to the transmitter.

3.4.5 Antenna Gain Characteristics. The IUS antennas shall have TBD gain characteristics. (See paragraph 3.3.3).

3.4.6 Telemetry Downlink Calculations

<u>Parameter</u>	<u>Nominal Value</u>
IUS transmitter power	TBD (1-watt typical)
IUS line losses	TBD

<u>Parameter</u>	<u>Nominal Value</u>
IUS diplexer losses	TBD
IUS antenna gain	TBD
Polarization loss	TBD
Space loss at TBD nmi	TBD
Atmospheric attenuation	TBD
Received power at the ground antenna	TBD

3.5 IUS UPLINK

The uplink carrier is directly phase-modulated by a composite signal consisting of the PRN ranging signal and the frequency-shift keyed command subcarrier frequencies representing the ternary 1, 0 and S command data.

3.5.1 RF Configuration

<u>Characteristic</u>	<u>Requirement</u>
Frequency range (assigned limits)	1750 to 1850 MHz (20 standard SGLS carrier frequencies)
Receiver carrier frequency assignment	TBD (mission peculiar)
Receiver noise threshold S/N	TBD
Receiver frequency accuracy	±0.002 percent
Command modulation technique	Ternary FSK, amplitude modulated with clock waveform
Command rate	1 or 2 Kilobaud, ±20 percent
Command subcarrier frequency assignments	65 (S), 76 (0) and 95 (1) kHz ±0.4 kHz
Composite command modulation loss (modulation index = 0.3 radian for both commands and PRN)	14.0 dB
PRN ranging data	NRZ-L at 500 kb/s
Composite PRN ranging modulation loss (modulation index = 0.3 radian for both commands and PRN)	10.8 dB
Transmission loss from diplexer to either receiver	TBD

3.5.2 Types of Commands. TBD

3.5.3 Command Tone Demodulator/Decoder

3.5.3.1 Signal Reception and Initial Processing. TBD

3.5.3.2 PRN Ranging. The PRN uplink modulation is detected by the phase-locked spacecraft receiver, and the PRN output is supplied to the dual baseband assembly for carrier modulation and transmission back to the ground station on the telemetry downlink. PRN ranging is available in the coherent mode only. The coherent mode exists when transmitter No. 1 is operating with receiver No. 1 or transmitter No. 2 is operating with receiver No. 2.

3.5.3.3 Command Modulation. The command carrier modulation consists of three subcarriers turned on one at a time. The subcarrier frequencies, listed in paragraph 3.5.1, are assigned to represent an S, 0, or a 1. A clock signal is amplitude-modulated on the subcarrier signal. The subcarriers are individually keyed at the ground station by digital information transmitted from the command generator on three digital lines. Condition S, 0, or 1 is transmitted by turning on the corresponding subcarrier f_a , f_b , or f_c , one subcarrier at a time, in FSK fashion. The bit-synch information (clock) amplitude modulates the keyed subcarrier with a triangular wave at half the bit rate and in suitable phase.

3.5.3.4 Signal Conditioning. TBD

3.5.3.5 Command Decoding. TBD

3.5.3.6 Command Processing. TBD

3.5.4 Command Word Structure. TBD

3.5.5 Command Verification. TBD

3.5.6 Command Uplink Calculation

<u>Parameter</u>	<u>Nominal Value</u>
Ground station transmitter power: 10 kw (dBm)	+70.0
Ground station line losses transmitter to antenna (dB)	-0.6

<u>Parameter</u>	<u>Nominal Value</u>
Ground station antenna gain (60 f ⁺ . dish RHCP) (dB)	+46.0
Ground station radome loss (dB)	-0.6
Atmospheric attenuation (dB)	-TBD
Polarization losses (dB)	-0.2
Space loss at TBD nmi (dB)	TBD
IUS receiver antenna gain ±X deg beamwidth (dB)	+TBD
IUS duplexer losses (dB)	-TBD
IUS line losses (dB)	-TBD
Received power at IUS (dBm)	-TBD

3.5.7 Antenna Characteristics. TBD.

SECTION 4

DETAILED SUPPORT REQUIREMENTS

4.1 PAD CHECK REQUIREMENTS

SFC support required for the IUS only is as follows:

- Mission support planning
- Software coordination
- IUS/SCF compatibility tests
- Coordination of data base

4.1.1 Mission Support Planning. Planning support is required to coordinate program requirements with SCF support capability, with emphasis on software program interface capability and hardware.

4.1.2 Software Coordination. Special coordination is required between contractors and KSC to ensure compatibility between pre-launch command and telemetry checkout and KSC support/software capability. Normal coordination activities are required in the preparation of telemetry modes for data display which are compatible with the IUS telemetry format.

4.1.3 IUS/SCF Compatibility Tests. Tests will be required at KSC to verify the interface compatibility of the IUS Tracking, Telemetry, and Command (TT&C) Subsystem (using engineering model hardware) with the SCF/SGLS hardware. Magnetic tapes of simulated IUS telemetry data will be provided by the contractor to verify telemetry modes and for use in rehearsals.

4.1.4 Coordination of Data Base. Data base tables are required for the communications ground terminals which will support the Orbiter during deployment, mission and recovery of the IUS (when applicable). The information required in the tables is TBD.

4.2 COUNTDOWN REQUIREMENTS

There are no IUS-peculiar requirements on the SCF during the countdown. Upon request from KSC, during the countdown, the SCF will be required to report its readiness status via voice link to KSC.

4.3 ASCENT REQUIREMENTS

4.3.1 Definition. The ascent phase for this ORD is from liftoff at KSC through separation of boosters and external tanks and injection of the Orbiter into orbit.

4.3.2 Tracking Requirements. There are no tracking requirements peculiar to the IUS during ascent.

4.3.3 Communications. A voice link is required between the KSC and the Orbiter during ascent for backup reporting of IUS status.

4.4 ON-ORBIT REQUIREMENTS

The SCF is required to provide prime support to IUS orbital operations after deployment from the Orbiter. The support required is listed in three general categories: maneuvers, communications, and IUS operations.

4.4.1 Maneuvers. During deployment, maneuver, and recovery of the IUS, the SCF shall provide backup positional data to the Orbiter or guidance update directly to the IUS. These updates, as well as IUS/RTS telemetry, shall be via standard SGLS.

4.4.2 Communications. SCF communications will be required during TBD portions of the IUS flight, as lines of sight permit. Detailed utilization of the existing net is TBD, and will be mission-peculiar.

4.4.3 IUS Operations. Events requiring SCF support include backup command transmission, vehicle tracking, data reception, display and recording. Specific details are TBD and are mission-peculiar.

4.5 TRACKING REQUIREMENTS

4.5.1 SCF Tracking Support. Tracking is required of the SCF to meet the specified time and accuracy requirements for updating of the IUS ephemeris, to support station handover, command positional update, and telemetry reception. Detailed tracking requirements are TBD and are mission-peculiar.

4.5.1.1 Station Acquisition. The activities which will be supported, and the timelines for groundtracking, are mission-peculiar. After IUS deployment, tracking is required for the determination of the orbit parameters and the prediction of on-station arrival time. During and after deployment, sufficient tracking time per day will be allotted to support IUS accuracy requirements.

4.5.1.2 Repositioning. Ephemeris requirements for IUS update and maneuvering are TBD.

4.5.2 IUS Tracking Planning. The operational planning of IUS tracking will be as follows.

4.5.2.1 Normal Operation. A schedule of normal trajectory and maneuvers will be determined in advance and transmitted to the field test flight director (FTFD). The ephemeris will be determined in accordance with the planned operation and will be provided as an input to the station processor for generation of tracking slave data and backup commanding.

4.5.2.2 Contingency Operation. In the event of contingencies in IUS operation SCF support is TBD.

4.6 EPHEMERIS ACCURACY REQUIREMENTS

4.6.1 IUS Ephemeris. The accuracy required for the IUS ephemeris will vary with the mission phase and is summarized in table 4.6-1.

TABLE 4.6-1

SATELLITE EPHEMERIS DATA REQUIREMENTS

MISSION PHASE	TRACKING PHASE	ACTIVITIES SUPPORTED BY EPHEMERIS DATA	MAXIMUM ALLOWABLE TRACKING TIME (HR)	MAXIMUM (3σ) EPHEMERIS ERROR			
				DRIFT RATE (DEG/DAY)	TANG (1) VELOCITY (FPS)	RADIAL (1) POSITION (NMI)	TANG POSITION (NMI)
TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

(1) CORRESPOND TO DRIFT RATE ERROR, WHICH IS EQUALLY DIVIDED OVER BOTH ERRORS. ERRORS ARE ASSUMED TO BE 100 PERCENT CORRELATED (WORST CONDITION).

4.7 TELEMETRY REQUIREMENTS

4.7.1 Telemetry Support. The requirements for the acquisition of telemetry data at the SCF stations are as follows.

4.7.1.1 Launch Phase. There are no requirements for direct telemetry support through deployment of the IUS from the Shuttle. Indirect support will be achieved via the Shuttle avionics.

4.7.1.2 Drift Orbit. A TBD-minute sample of telemetry data is to be recorded by the SCF in the general telemetry mode (paragraph 4.7.4) every TBD hours up to initial injection into the final orbit or deployment of the payload satellite(s).

4.7.1.3 Stationing On-Orbit. Continuous telemetry coverage is required during all commanding in order to arrest and trim drift-orbit velocity for station positioning on-orbit.

4.7.1.4 Attitude/Orbit Maneuvers

A. Continuous telemetry coverage by the SCF is required during all orbit and/or attitude maneuver from TBD minutes prior to the first command through TBD minutes after the final command.

B. A TBD sample of telemetry data (general mode) is required TBD seconds following each attitude/orbit maneuver.

4.7.1.5 Recording Requirements. All telemetry data received at the STC from first acquisition until end of mission will be retained for a period of TBD at the STC on magnetic tape. The IUS downlink data rate is in accordance with standard SGLS. During this TBD period the systems program office (SPO) may request data printed out in various modes.

Recording equipment shall not add errors to the data stream at a rate greater than TBD when measured at the recorder output for reproduced data, referenced to error-free recorder input data.

The telemetry report format is TBD.

1.7.2 Description of the Telemetry List. The description of the telemetry list, including explanation of column headings and sorting technique, will be specified for individual missions.

4.7.3 Telemetry Modes. The number and type of telemetry modes are mission-peculiar.

4.7.4 Telemetry Mode Format. All telemetry modes will be designed for printing in the same general format. The specifics of this format are TBD.

4.8 CONTROL AND DISPLAY REQUIREMENTS

4.8.1 SMCC Control and Display (C&D). Displays are required at the SMCC for Technical Advisor use to display the TLM data as specified in paragraph 4.7. These displays will be required throughout the entire mission. Other C&D requirements are TBD.

4.9 COMMANDING REQUIREMENTS

4.9.1 Command Process Requirement

4.9.1.1 General Command Operations. Command to the IUS will be generated by the SMCC. Command transmission to the IUS is via the SGLS which may be secure, if required. The authority to transmit types of commands is detailed in paragraph 4.9.1.3.

Single or block commands will be transmitted. The receipt of commands by the IUS will be verified by telemetry data prior to the transmission of subsequent commands. Alarms occurring during command transmissions must be investigated and analyzed as to possible effects on IUS operation prior to transmitting subsequent commands. At the end of each command operation, the RTS will forward to the Shuttle Mission Control Center (SMCC) a summary of the commands transmitted to the IUS.

4.9.1.2 SCF Support. The IUS will be supported by the SCF in the following manner:

- A. Command Sources. Commands which will be sent to the IUS by the RTS may emanate from either the command program calculations under the control of the mission controller or from a procedure available to the test controller.
- B. Time-Tagged Commands. Commands sent to the IUS may be time tagged. The RTS will comply with the time-tag on the commands within TBD seconds.

4.9.1.3 Command Authorization. The authorization of commands prior to transmission to the IUS will be vested in user agencies, which will work through the SMCC.

4.9.2 Command Description. Detailed requirements imposed upon the SCF for IUS commanding clearly must be delayed until the IUS vehicle is defined; since the vehicle is still in the conceptual stage as of the initial issue date of this document, all such command requirements are necessarily TBD. Specifications will eventually evolve for commanding IUS subsystems by SCF ground stations, as follows:

- Communications Subsystems
- Control Subsystem

- Electrical Power Subsystem
- TT&C Subsystem
- Electrical Distribution System
- Structures Subsystem
- Propulsion Subsystem
- Thermal Control Subsystem
- Satellite Separation Subsystem

4.10 DATA HANDLING AND DATA DISTRIBUTION REQUIREMENTS

The data required by the SCF during operational mission consists primarily of:

- Ephemeris
- Data base
- IUS status reports
- IUS telemetry printouts
- Command program data printouts
- Command summary
- KSC reports

Distribution of each of the above items is listed in tables 4.10-1 and 4.10-2.

TABLE 4.10-1

DISTRIBUTION OF KSC GENERATED DATA

ITEM	DESCRIPTION	FORMAT	RECIPIENT	COPIES	TIME SCALE
1	EPHEMERIS	PRINTOUT	TBD	1	AS PRODUCED
2	EPHEMERIS	PRINTOUT/MAG TAPE	TBD	1 EA	WITH DATA BASE
3	DATA BASE	PRINTOUT	TBD	1	AS PRODUCED
4	DATA BASE	PRINTOUT/MAG TAPE	TBD	1 EA	AS PRODUCED
5	TELEMETRY	PRINTOUT	TBD	1	TBD
6	COMMAND PROGRAM DATA				
7	COMMAND SUMMARY	PRINTOUT	TBD	1	TBD

TABLE 4.10-2

DISTRIBUTION OF KSC GENERATED REPORTS

ITEM		RECIPIENT	COPIES	DELIVERY	PAR. REF
1	OPERATIONS REPORT	TBD	TBD	TBD	4.15.1.1
2	COMMAND PASS PLOT	TBD	TBD	TBD	4.15.1.2
3	COMMAND PASS PLAN	TBD	TBD	TBD	4.15.1.2
4	VEHICLE CONFIGURATION LOG	TBD	TBD	TBD	4.15.1.2
5	VEHICLE STATUS LOG	TBD	TBD	TBD	4.15.1.2

4.11 COMPUTER PROGRAM DEVELOPMENT

4.11.1 Scope. The IUS contractor will develop a computer program to support IUS operation associated with attitude determination and correction, station acquisition and maintenance, and the planning and command generation necessary for accomplishing these operations. The program will be written in TBD language for use on a TBD computer in the standard configuration and software environment and shall be compatible with Launch Processing System (LPS) processors as well as SCF processing systems.

4.11.2 Command Program Functions. The program will support and/or conduct the following functions and the executive control thereof:

- Attitude determination
- Attitude maneuver command data generation
- Orbital maneuver planning and command data generation
- Retrieval maneuvers and safing command data generation
- Telemetry data processing relevant to the above.

The general performance capabilities applicable to subprograms of the program are:

- A. Present summary data for online decision control, with provision for outputting detailed data (normally preserved for offline listing and analysis), preselectable by user option. In general, online output data will include information required to facilitate validity evaluations and performance assessments by user personnel.
- B. Provide the optional capability to override (but not replace) control and state parameters in the data base by means of function card input.
- C. Format the command sequences both for manual validity, checking at the SMCC and for transmission to the RTS's and Shuttle for command backup. These command sequences will include commands for preconditioning the vehicle and time tags for time-critical commands when applicable.

- D. Interface with STS Orbit Ephemeris System functions, procedures and/or subroutines for IUS ephemeris data and orbital prediction.

4.11.3 Milestone Schedule. The milestone schedule for the command program software is illustrated in table 4.11-1. Also included is a milestone schedule for Model TBD software at the SCF which is required to support the program.

TABLE 4.11-1
COMMAND PROGRAM MODELS AND SCHEDULE

TBD

4.12 TIMING REQUIREMENTS

The standard SCF timing system which measures time of day in total seconds is required on all printouts and command summary printouts. Time is referenced to GMT. Telemetry printout data lines will be time tagged to the nearest whole second at the start of the data frame. Command summary printouts will be time-tagged to the nearest whole second at the initiation of the transmission of the command word.

Command Program data printouts require the time of calculated commands measured by year, month, day, hour, minute and seconds (GMT).

4.13 COMMUNICATIONS REQUIREMENTS

The following communications links are required for IUS operations:

- A. Wideband data links between the STC/SMCC and the RTS's. IUS operations require a downlink for a data rate of 16 kb/s and uplink data rate (commands) of 1 or 2 kilobauds.
- B. Data links between STC/SMCC and the RTS's for the transmission of prepass data commands, antenna pointing data and ranging data.
- C. Voice and teletypewriter links between the STC/SMCC and the RTS's for control, coordination and administrative functions.
- D. Circuits described in a, b and c between the STC and KSC for launch coordination.

4.14 FACILITIES REQUIREMENTS

The following additional facilities will be required for IUS operations:

TRD

4.15 OTHER REQUIREMENTS

4.15.1 STC/SMCC Reports. TBD

4.15.2 Data Base. The STC/SMCC shall provide a data base in support of IUS scheduling and acquisition times. The information in the data base will be supplied for each mission via magnetic tape. The required data to be provided for each mission data base includes:

- Ground trace table
- RTS acquisition table
- Events tables

Rise and fade times (5° elevation points) for each RTS

Shuttle, IUS and payload conjunctions

- Orbital elements (ADBARV format may be specified)

The following descriptions provide specific definition of requirements for data derived from IUS ephemerides:

TBD